DECEMBER · 1954

# roceedings of the I·R·E

## Journal of Communications and Electronic Engineering

Illinois U. Library

Volume 42 Number 12

TRANSISTOR RADIO

*Regency*

ios employing transistors instead of tubes have emerged from the
tory and are now being produced on a commercial basis. The pocket
shown above uses four n-p-n junction transistors for the converter-mixer,
d audio stages, and a germanium diode for the detector.

IN THIS ISSUE

- Recent Advances in Microwave Tubes
- Man-Machine Control System Design
- Dielectric Potentiometers
- Large-Signal Behavior of Transistors
- Large-Signal Transient Response of Transistors
- Power Oscillator Amplitude Stability
- Reduced Range of a Radar
- Miniature Lacquer Film Capacitors
- *Transactions* Abstracts
- Abstracts and References
- Annual Index to *Proceedings*

TABLE OF CONTENTS INDICATED BY BLACK-AND-WHITE MARGIN, FOLLOWS PAGE 80A

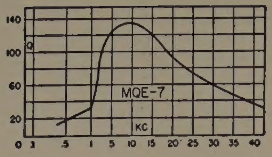
he Institute of Radio Engineers

# HIGH Q INDUCTORS
## FOR EVERY APPLICATION

**FROM STOCK...** ITEMS BELOW AND 650 OTHERS IN OUR CATALOGUE B.

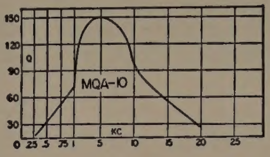
### MQ Series
### Compact Hermetic
### Toroid Inductors

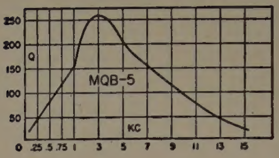
The MQ permalloy dust toroids combine the highest Q in their class with minimum size. Stability is excellent under varying voltage, temperature, frequency and vibration conditions. High permeability case plus uniform winding affords shielding of approximately 80 db.



**MQE**
15 stock values
from 7 Mhy.
to 2.8 Hy.

**MQA**
19 stock values
from 7 Mhy.
to 22 Hy.

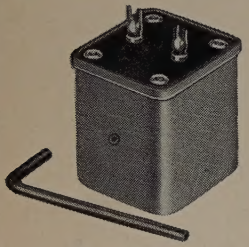




**MQB**
12 stock values
from 10 Mhy.
to 25 Hy.

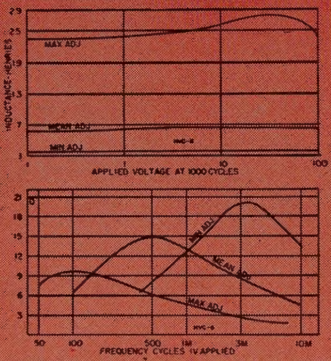
MQ drawn case structure.

| | Length | Width | Heig |
|---|---|---|---|
| MQE | 1/2 | 1-1/16 | 1-7/ |
| MQA | 11/16 | 1-9/32 | 1-23/ |
| MQB | 1-5/16 | 2-9/16 | 2-13/ |



VIC case structure

| Length | Width | Height |
|---|---|---|
| 1-1/4 | 1-11/32 | 1-7/16 |



| Type | Mean Hys. | Type | Mean Hys. |
|---|---|---|---|
| VIC-1 | .0085 | VIC-12 | 1.3 |
| VIC-2 | .013 | VIC-13 | 2.2 |
| VIC-3 | .021 | VIC-14 | 3.4 |
| VIC-4 | .034 | VIC-15 | 5.4 |
| VIC-5 | .053 | VIC-16 | 8.5 |
| VIC-6 | .084 | VIC-17 | 13. |
| VIC-7 | .13 | VIC-18 | 21. |
| VIC-8 | .21 | VIC-19 | 33. |
| VIC-9 | .34 | VIC-20 | 52. |
| VIC-10 | .54 | VIC-21 | 83. |
| VIC-11 | .85 | VIC-22 | 130. |

### VIC Variable Inducto

The VIC Inductors have repr
sented an ideal solution to th
problem of tuned audio circuit
A set screw in the side of t
case permits adjustment of t
inductance from +85% to —45
of the mean value. Setting
positive.

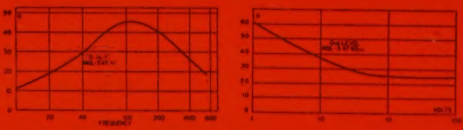
Curves shown indicate effecti
Q and L with varying frequen
and applied AC voltage.

### MQL Low Frequency High Q Coils

The MQL series of high Q coils employ special laminated Hipermalloy cores to provide very high Q at low frequencies with exceptional stability for changes of voltage, frequency, and temperature. Two identical windings permit series, parallel, or transformer type connections.

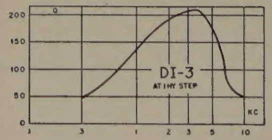
| | |
|---|---|
| MQL-1 | 2.5/10 Hys. |
| MQL-2 | 5/20 Hys. |
| MQL-3 | 50/200 Hys. |
| MQL-4 | 100/400 Hys. |

MQL case
1-13/16 dia. X 2-1/2" H.

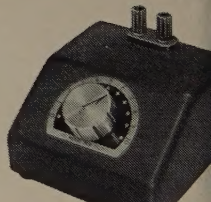


### DI Inductance Decades

These decades set new standards of Q, stability, frequency range and convenience. Inductance values laboratory adjusted to better than 1%. Units housed in a compact die cast case with sloping panel ideal for laboratory use.



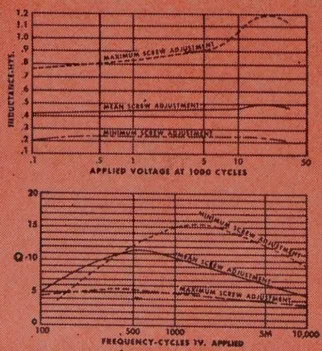
| | |
|---|---|
| DI-1 | Ten 10 Mhy. steps. |
| DI-2 | Ten 100 Mhy. steps. |
| DI-3 | Ten 1 Hy. steps. |
| DI-4 | Ten 10 Hy. steps. |



DI DECADE
Length ..........41
Width ..........43
Height ..........23

### HVC Hermetic
### Variable Inductors

A step forward from our long established VIC series. Hermetically sealed to MIL-T-27 . . . extremely compact . . . wider inductance range . . . higher Q . . . lower and higher frequencies . . . superior voltage and temperature stability.



| Type No. | Min. Hys. | Mean Hys. | Max. Hys. |
|---|---|---|---|
| HVC-1 | .002 | .006 | .02 |
| HVC-2 | .005 | .015 | .05 |
| HVC-3 | .011 | .040 | .11 |
| HVC-4 | .03 | .1 | .3 |
| HVC-5 | .07 | .25 | .7 |
| HVC-6 | .2 | .6 | 2 |
| HVC-7 | .5 | 1.5 | 5 |
| HVC-8 | 1.1 | 4.0 | 11 |
| HVC-9 | 3.0 | 10 | 30 |
| HVC-10 | 7.0 | 25 | 70 |
| HVC-11 | 20 | 60 | 200 |
| HVC-12 | 50 | 150 | 500 |

HVC case structure.

| Width | Length | Hei |
|---|---|---|
| 25/32 | 1-1/8 | 1-7/ |

**SPECIAL UNITS TO YOUR NEEDS**

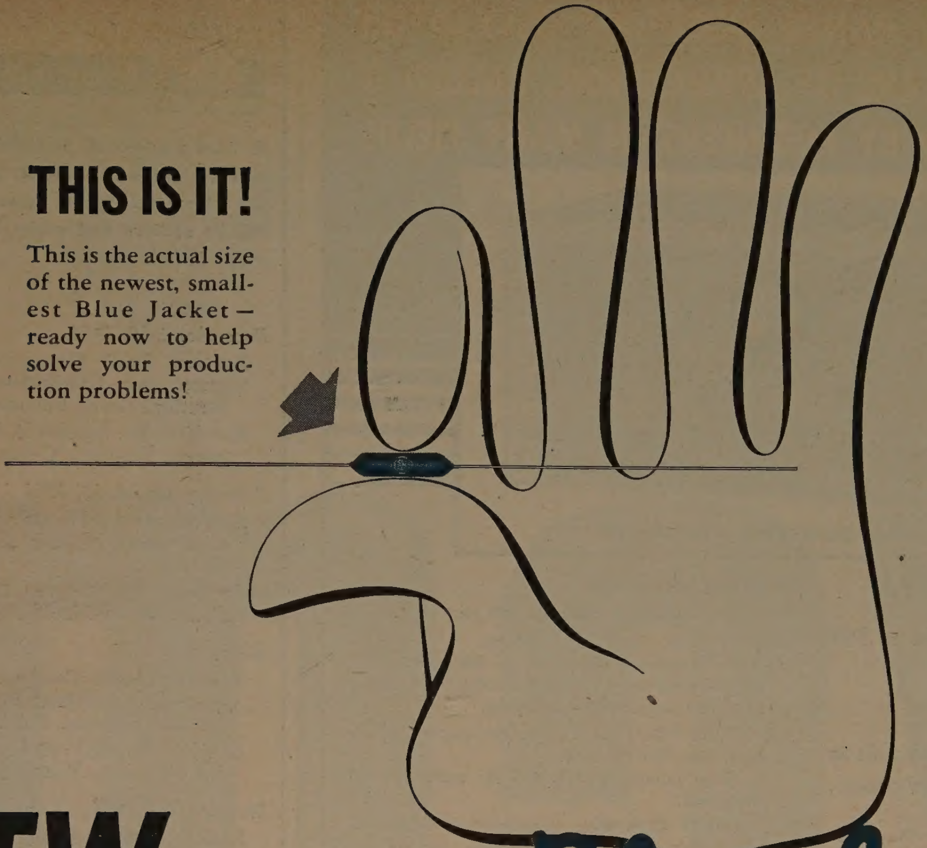
**Send your specifications**

## UNITED TRANSFORMER CO

150 Varick Street, New York 13, N. Y. EXPORT DIVISION: 13 E. 40th St., New York 16, N. Y. CABLES: "ARLA

## THIS IS IT!

This is the actual size of the newest, smallest Blue Jacket—ready now to help solve your production problems!



# NEW...a 3-watt Blue Jacket®

## miniaturized axial-lead wire-wound resistor

This power-type wire wound axial-lead Blue Jacket is hardly larger than a match head *but it performs like a giant!* It's a rugged vitreous-enamel coated job—and like the entire Blue Jacket family, it is built to withstand severest humidity performance requirements.

Blue Jackets are ideal for dip-soldered sub-assemblies . . . for point-to-point wiring . . . for terminal board mounting and processed wiring boards. They're low in cost, eliminate extra hardware, save time and labor in mounting!

Axial-lead Blue Jackets in 3, 5 and 10 watt ratings are available without delay in any quantity you require. ★ ★

| SPRAGUE TYPE NO. | WATTAGE RATING | DIMENSIONS L (inches) | D | MAXIMUM RESISTANCE |
|---|---|---|---|---|
| 151E | 3 | 11/32 | 13/64 | 6,000 Ω |
| 27E | 5 | 1 1/8 | 5/16 | 30,000 Ω |
| 28E | 10 | 1 7/8 | 5/16 | 50,000 Ω |

Standard Resistance Tolerance: ±5%

27E
5W
30,000Ω

WRITE FOR ENGINEERING BULLETIN NO. 111B

**SPRAGUE**

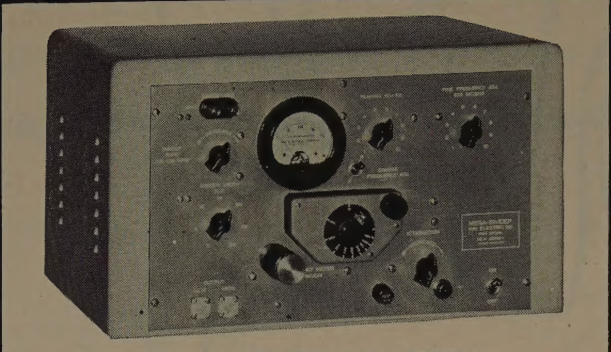
28E
10W
50,000Ω

PRAGUE ELECTRIC COMPANY · 235 MARSHALL ST. · NORTH ADAMS, MASS

PROCEEDINGS OF THE I.R.E. December, 1954, Vol. 42, No. 12. Published monthly by the Institute of Radio Engineers, Inc., at 1 East 79 Street, New York 21, N.Y. Price per copy: members of the Institute of Radio Engineers $1.00; non-members $2.25. Yearly subscription price: to members $9.00; to non-members in United States, Canada and U.S. Possessions $18.00; to non-members in foreign countries $19.00. Entered as second class matter, October 26, 1927, at the post office at Menasha, Wisconsin, under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28, 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized October 26, 1927.

Table of Contents will be found following page 80A

**A VERY WIDE RANGE SWEEPING OSCILLATOR PROVEN BY YEARS OF APPLICATION. VALUED & RECOMMENDED BY ENGINEERS IN MANY FIELDS**



110-A CALIBRATED MEGA-SWEEP

**FEATURES — Model 110A**

Wide Range—from 50 kc to 950 mc.

Single Dial Tuning

Wide Sweep Width Adjustable to 30 mc (wider on special order).

Very Flat Amplitude vs. Frequency Response.

Precision Micrometer-controlled Wavemeter.

High Stability, Negligible Distortion.

Sawtooth Sweep Voltage Available for Deflecting Oscilloscope.

Electronically Regulated Power Supply.

**SPECIFICATIONS:**

FREQUENCY RANGE: 50 kc to 950 mc.

SWEEP WIDTH: Variable to 30 mc.
*Note:* Frequency sweeps up to 60 mc in width may be obtained with slight sacrifice in constancy of signal output while sweeping.

R.F. OUTPUT VOLTAGE: High output, approx. 50 mv max. into 50 ohm load.
Low output, approx. 2.5 mv max. into 50 ohm load.

R.F. OUTPUT CONTROL: Uncalibrated microwave attenuator continuously variable to 26 db. Attenuation characteristic flat over frequency range.

FREQUENCY MEASUREMENTS: Approx. output center frequency indicated by a calibrated dial accurate to about 10%. In addition, center frequency of sweep may be pre-set or frequency indicated at any point on oscilloscope display within ± 5 mc by use of the precision micrometer-controlled wavemeter.

AMPLITUDE MODULATION: Control of output signal amplitude by fixed frequency klystron produces an amplitude variation while sweeping of less than 0.1 db per mc.

CATALOG No. 110-A.

PRICE: $495.00 f.o.b. factory.

**ALSO THREE OTHER MODELS . . .**

**MEGA-SWEEP**

Same as Calibrated Mega-Sweep, except:

1. Center frequency control not calibrated.
2. Variable klystron repeller voltage peaking controlled manually instead of automatically.
3. Frequency range: 50 kc to 1000 mc.

CATALOG No. 100-A.

PRICE: $465.00 f.o.b. factory.

**III-A MEGA-SWEEP**

Same as Calibrated Mega-Sweep, plus:

1. Much higher output
2. Wider Sweep Width (to 40 mc)
3. Zero Level Baseline.

EXCEPT:

| | Frequency Range | Output Impedance | Output Voltage (into 70 ohm load) |
|---|---|---|---|
| 1. | 10 mc to 950 mc | 70 ohms unbalanced | 0.15 volts |
| 2. | 450 mc to 900 mc | 300 ohms balanced | 0.3 volts |

CATALOG No. 111-A

PRICE: $575.00 f.ob. factory, including Ultra-Former.

**112-A MEGA-SWEEP**

Same as 111-A Mega-Sweep, except frequency range is 800 mc to 1200 mc

**KAY ELECTRIC COMPANY**

14 Maple Avenue Pine Brook, New Jersey

## Meetings with Exhibits

● As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups which include exhibits.

Δ

*December 8-10, 1954*

**Eastern Joint Computer Conference and Exhibition,** Bellevue-Stratford Hotel, Philadelphia, Pa.

*Exhibits:* Mr. Stanley B. Disson, Burroughs Research Center, Paoli, Pa.

*February 10, 11, 12, 1955*

**Seventh Annual Southwestern IRE Conference,** Baker Hotel, Dallas, Texas

*Exhibits:* T. W. Sharpe, Collins Radio Co., 1930 Hi-Line Drive, Dallas 2.

*March 1-3, 1955*

**Western Joint Computer Conference and Exhibition,** Hotel Statler, Los Angeles, Calif.

*Exhibits:* Mr. William L. Martin, 5230 Norwich Ave., Van Nuys, Calif.

*March 21-24, 1955*

**Radio Engineering Show and I.R.E. National Convention,** Kingsbridge Armory and Kingsbridge Palace, N.Y.C.

*Exhibits:* Mr. William C. Copp, Institute of Radio Engineers, 1475 Broadway, New York 36, N.Y.

*April 27-29, 1955*

**Seventh Region Technical Conference,** Hotel Westward Ho, Phoenix, Ariz.

*Exhibits:* Mr. George McClarathan, 509 East San Juan Cove, Phoenix, Ariz.

*May 9-11, 1955*

**National Conference on Aeronautical Electronics,** Biltmore Hotel, Dayton, Ohio

*Exhibits:* Mr. William Klein, 1472 Earlham Drive, Dayton, Ohio

*May 18-20, 1955*

**National Telemetering Conference,** Morrison Hotel, Chicago, Ill.

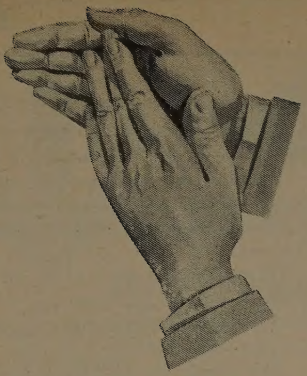
*Exhibits:* Mr. Kipling Adams, General Radio Company, 920 S. Michigan Ave., Chicago, Ill.

*May 26, 27, 1955*

**Electronic Components Conference,** Los Angeles, Calif.

*Exhibits:* Dr. Simon Ramo, Ramo-Wooldridge Corp., 8820 Bellanca Ave., Los Angeles 45, Calif.

*Note on Professional Group Meetings:* Some of the Professional Groups conduct meetings at which there are exhibits. Working committeemen on these groups are asked to send advance data to this column for publicity information. You may address these notices to the Advertising Department, and of course listings are free to IRE Professional Groups.



Be sure with Q-Max...the finest coil lacquer for VHF and UHF service. Q-Max imparts a clear, practically loss-free covering, penetrates deeply to seal out moisture, promotes rigidity and electrical stability. Q-Max is easily applied, adheres to practically any material...dries fast!

# max*

*REGISTERED TRADE NAME

# A-27 *RF* LACQUER

MANUFACTURED
EXCLUSIVELY BY

*Communication Products Company, Inc.*
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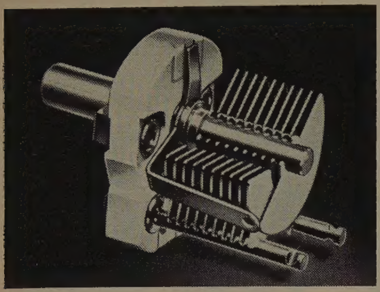
# NEWS and NEW PRODUCTS

December 1954

## Variable Capacitors

APC and MAPC type variable capacitors with extended shafts are now available through authorized distributors, according to **The Hammarlund Manufacturing Co., Inc.,** 460 W. 34th St., New York 1, N. Y.



In the past these items have been available only without shafts for adjustment with screwdriver but, they are now being made available with the half-inch shaft extension for knob control.

The original APC trimmer was designed and first produced by Hammarlund more than 20 years ago, and is used in all classes of equipment where an air dialectic trimmer is needed. The MAPC-type is similar to the APC except that it is a miniaturized version.

## Torodial Inductor Bulletin

Two types of precision-wound toroidal inductors are listed in a new bulletin TL2-P4 released by **Lenkurt Electric Sales Co.,** 1129 County Rd., San Carlos, Calif. Both types are available in six different sizes with various Q's and inductance ranges.

One coil type is wound on Carbonyl Iron cores for high frequency applications with inductance values from 0.15 millihenries to 1.0 henries. The other is wound on Molydbenum-Permalloy cores for low frequency applications with inductance values from 2.0 millihenries to 9.9 henries.

*Q* curves, dimensions, and other data fully describing each type of coil are included in the new bulletin. All coils are specially wound to within one per cent of specified inductance value.

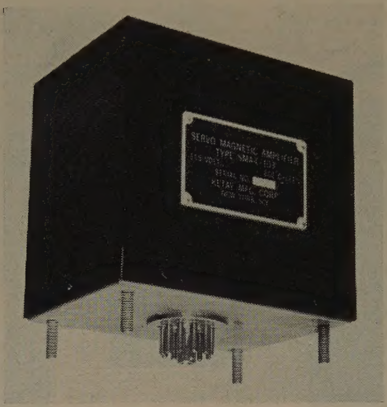
Copies of TL-P4 are available on request.

## Magnetic Amplifier

SMA 4-103 is a servo amplifier designed by **Ketay Manufacturing Corp.,** 555 Broadway. New York 12, N. Y., for use in servo systems employing 2 phase, 400 cps low inertia induction motors, and is suitable for operation with the following Ketay servo motors and servo units: K101660 (Mark 7), K402550 (Mark 8), K402300 (Mark 14) and 105P2C (Mark-12). It will also operate with other motors having control winding rated from 26 to 57 volts and 10 watts or less.

**These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.**

SMA 4-103 is an all-magnetic amplifier requiring no external tubes or separate bias supplies.



The electrical specifications of this unit are as follows: Power requirements, 115 volts, 400 cps; Load, Suited for above-listed servo motors; Input impedance, 10,000 ohms; Input signal, ac, dc, or pulse; Type of output, phase-reversible; Power gain (@ 0.5 v signal), 50,000 (approximately); Response time, 1/200 second (approximately); Standby power, 12 watts; Duty cycle, continuous; Ambient temperature ranges, −30°C to +55°C; −55°C to +71°C.

## Crystal Sweep Calibrator

The Model 238-1A Crystal Sweep Calibrator developed by **Loral Electronics Corp.,** 794 E. 140th St., New York 54, N. Y., for the purpose of oscilloscope time base calibration, has the following applications: sweep time calibration, marker generator, counter and computer calibrator, and frequency measurement.

LORAL
CRYSTAL SWEEP CALIBRATOR
SPACING
OUTPUT

The Model 238-1A produces narrow pulses spaced at intervals of 1, 10, 100, 1000 microseconds. Pulse spacing is accurate to ±0.01 per cent and is controlled by two precision crystals. Pulse spacing is selected by a five-position, front panel switch.

Output pulse widths of 0.1 of 1 microsecond are provided; selection is made by means of a panel switch.

Pulse outputs are positive and are preset by internal adjustments for each range to a level of 3.0 volts, output impedance is 93 ohms.

Output frequencies of 1 mc, 100 kc, 10 kc., 1 kc., and 100 cps are provided at the various pulse-spacing settings, by use of reciprocal scales.

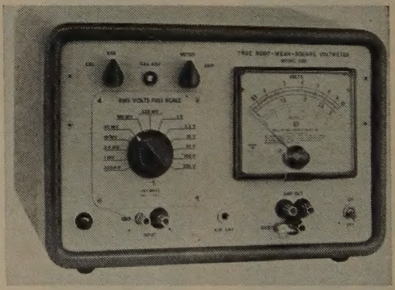
The Loral Crystal Sweep Calibrator is completely self-contained and operates on 115 volts ac, 50–420 cps. Power consumption is 50 watts.

The decade arrangement of pulse-spacing scales may be used for checking scalers and computers of various types.

## CORRECTION NOTICE

### RMS Voltmeter

Model 320, manufactured by **Ballantine Labs., Inc.,** Boonton, N. J., is a voltmeter of the ultra-sensitive type, designed to measure true root-mean-square values of highly complex wave forms, and sinusoidal waves. It operates over a range of 100 $\mu$v to 320 volts and in a band of 5 cps to 500 kc. Accuracy is better than 3 per cent between 15 cps and 150 kc for any reading regardless of scale position.

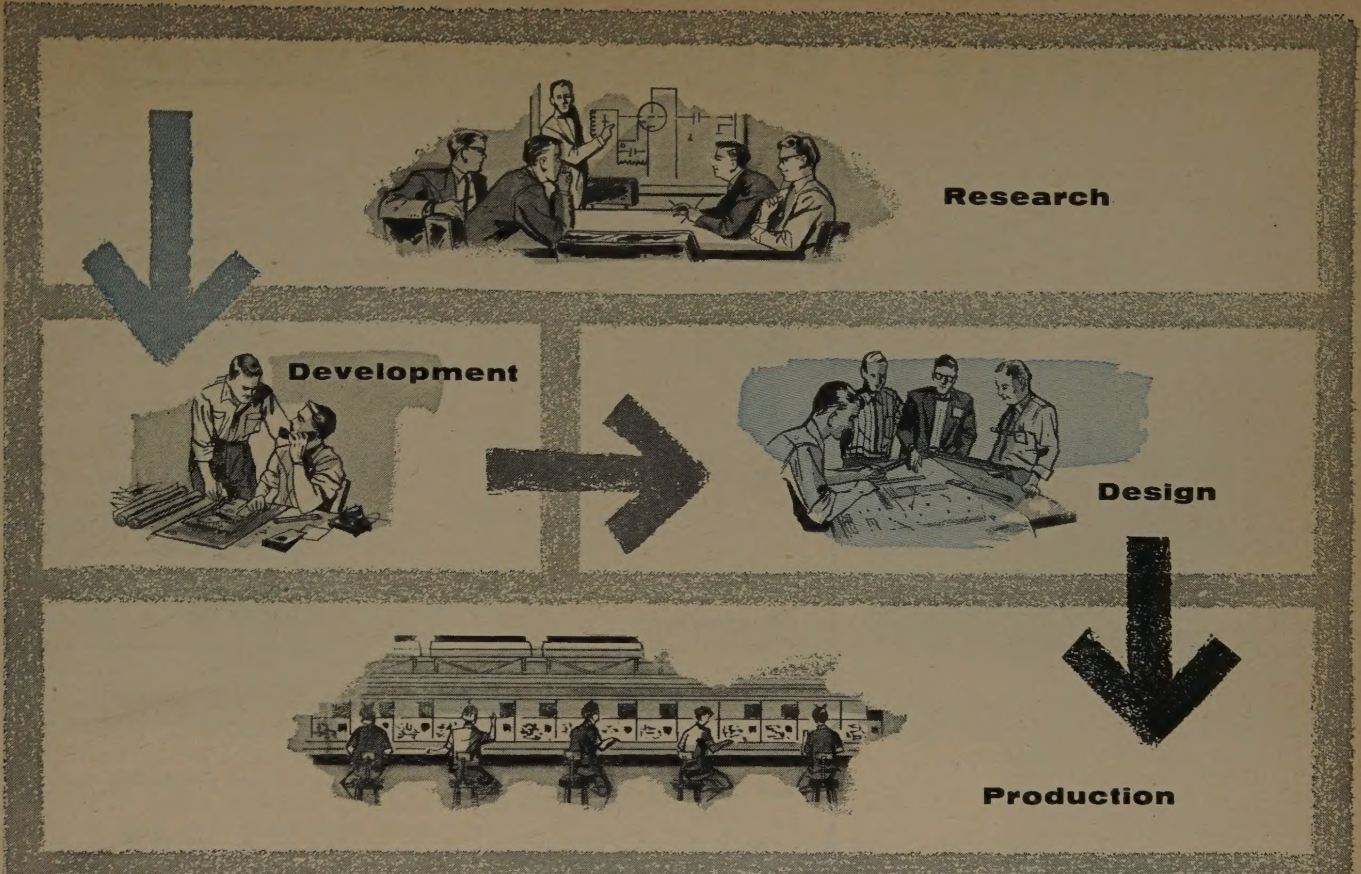


Other features include 10 megohm input impedance, provision for simultaneously observing the voltage reading and monitoring, the amplified signal with phones or CRO, and a built-in calibrator unit for correcting the effects of advanced aging of tubes. Accessories are available for extending voltage range to 20 $\mu$v and 10 kv and for measuring rms currents from 0.1 microampere to 10 amperes.

## Ceramics Bulletin

**American Lava Corp.,** Chattanooga 5, Tenn., has released a Bulletin #549 illustrating their latest ceramic developments. Thin, strong wafers which can be produced in intricate shapes as internal insulators for electron tubes

*(Continued on page 14A)*



## AN INTEGRATED ELECTRONICS OPERATION

- Navigational Gear
- Guided Missiles
- Radar
- Noise Rejection
- Counter Measures
- Computers
- Communications
- Terminal Equipment
- Transistors

Hoffman's reputation for getting things done is due, in part, to the unification of Research-Development-Design-Production into one closely integrated electronics operation. At Hoffman — instead of the usual four completely separate operations — one technical director is assigned to co-ordinate each new project from start to finish. Every new project is developed in close cooperation with the divisions ahead, including the practical problems of quantity production. This integration practically eliminates the all-too-common duplications and overlapping of functions, the errors and re-work caused by poor liaison, and materially cuts down the usual time lag between the testing of the prototype and actual production. Hoffman has become a leader in electronics by doing progressively complex jobs — to specifications — to cost estimates — and on schedule.

**Hoffman**
LABORATORIES, INC.
A SUBSIDIARY OF HOFFMAN RADIO CORP.

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**HOFFMAN LABORATORIES, INC.**
A Subsidiary of Hoffman Radio Corp.
3761 South Hill Street, Los Angeles 7, California

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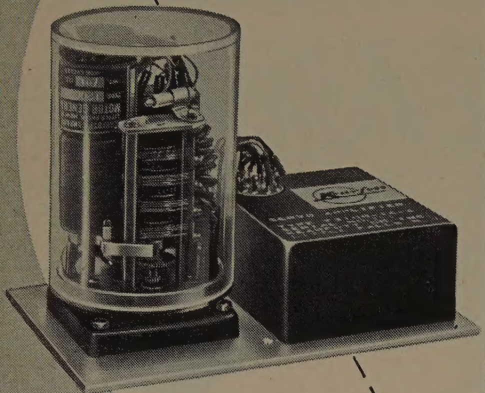
KEARFOTT ADAC



ADAC shown in plastic case is normally hermetically sealed in metal cover.

servo

**A**nalog

**D**igital

**A**nalog

**C**onverter

**ADAC is a device for the precise electro-mechanical conversion of analog information to digital form. ADAC works from a synchro voltage input and produces a 12-binary-digit informational output.**

This servo driven Converter is designed to be read-out either "on the run" or "on demand". For read-out, the digital computer sends an interrogating pulse to all the drums (and their segments) in common. The pulse can only return to the computer via the brushes contacting the tracks. If a brush is on a conducting segment, the pulse returns to the computer; if the brush is on an insulated segment, the pulse is blocked. All 12 tracks are simultaneously read and the return pulses are thus coded to represent discrete steps of the transducer feeding ADAC.

By using precision servo components, the accuracy of ADAC has been reduced to one part in 4096 (.02%), or approximately 5 minutes of transmitter rotation. It weighs only 2½ pounds and measures three inches in diameter and four inches in length. The device is hermetically sealed and is highly shock resistant. The T3100 Servo Amplifier provides the necessary excitation for the servo elements of the Converter. A direct drive ADAC providing the segmented drums and necessary gear trains, and an inverse ADAC for digital-analog conversion is available.

Let us send you complete data sheets. Write today.

**KEARFOTT COMPONENTS INCLUDE:**

Gyros, Servo Motors, Synchros, Servo and Magnetic Amplifiers, Tachometer Generators, Hermetic Rotary Seals, Aircraft Navigational Systems, and other high accuracy mechanical, electrical and electronic components.

Send for bulletin giving data of components of interest to you.

Kearfott

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**KEARFOTT COMPANY, INC., LITTLE FALLS, N. J.**

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Midwest Office: 188 W. Randolph Street, Chicago, Ill. South Central Office: 6115 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

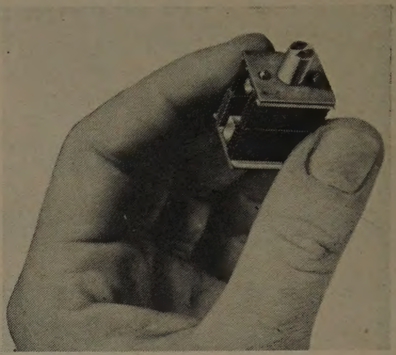
## News-New Products

**These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.**

*(Continued from page 10A)*

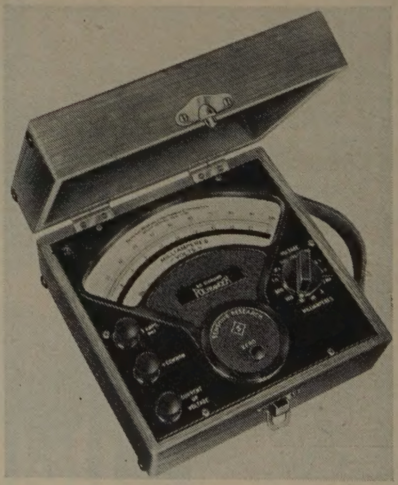
### Variable Capacitors

**McCoy Electronics Co.,** Mt. Holly Springs, Pa., announces the development of a new Mini-Dual Variable capacitor for sub-miniature receivers and sub-miniature transmitters. Dimensions, exclusive of shaft, are $\frac{13}{16}\times\frac{11}{16}\times1\frac{1}{16}$ inches. Capacitance range up to 385 $\mu\mu$f per section, with at least 10:1 ratio from maximum to minimum. Both "rotors" and both "stators" are isolated for flexibility of circuitry. Other specifications include: Shaft diameter, $\frac{3}{16}$ inches or $\frac{1}{4}$ inch. Standard shaft length, $\frac{3}{8}$ inch; Weight, $\frac{1}{2}$/ounce. Additional information is now available by writing to McCoy.



### DC Reference Standard

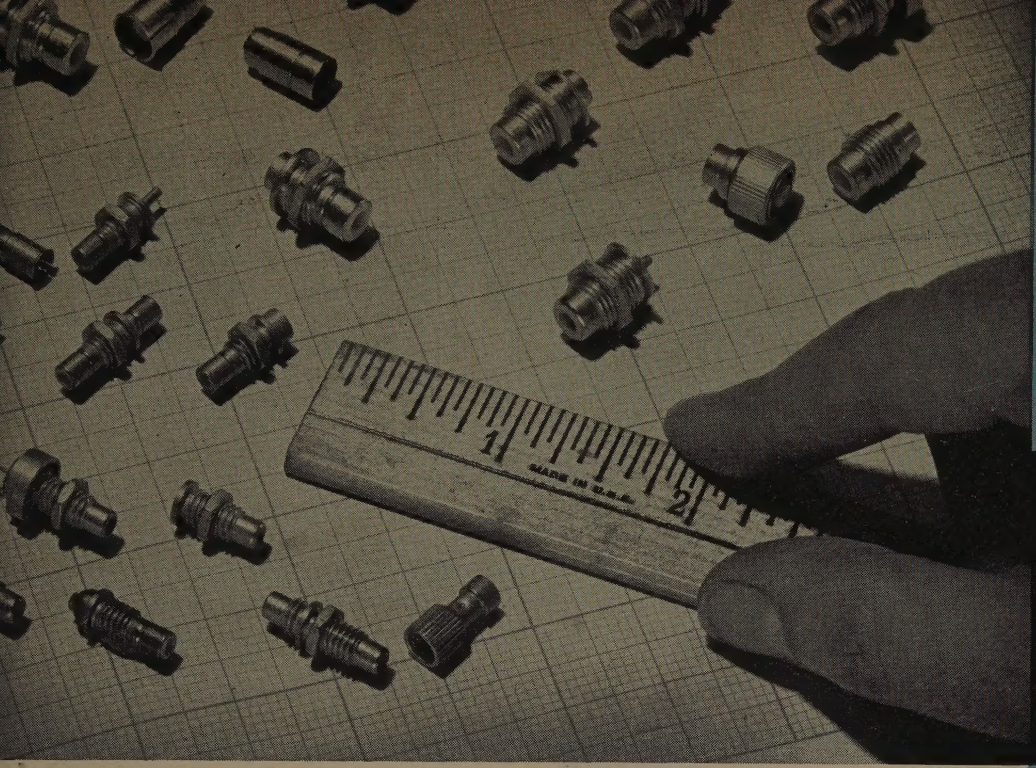
**Sensitive Research Instrument Corp.,** 9 Elm Ave., Mount Vernon, N. Y., is manufacturing a Model C Reference standard trade named Poly-Ranger.



The instrument has 14 ranges in dc voltage and current, an accuracy of $\frac{1}{4}$ of 1 per cent is claimed. Reading time is less than 1 second. An anti-parralax mirrored scale provides for a high degree of accuracy.

As a milliameter it reads down to 1 milliamper full scale (lowest reading 10 $\mu$a); as an ammeter, up to 10 amperes full scale; and as a voltmeter, down to 1 volt full scale and up to 1000 volts full scale.

*(Continued on page 94A)*



connectors are actual size

complete listing of

SPACE-SAVING
SUBMINAX
RF CONNECTORS

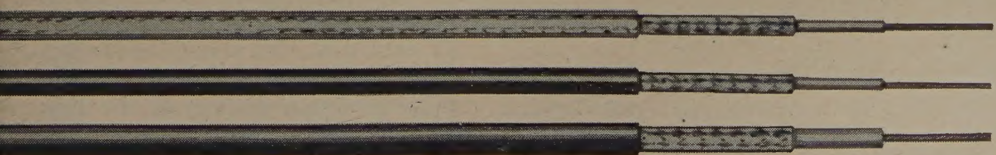
# the ruler tells the story...

## AMPHENOL SUBMINAX RF CONNECTORS

A complete line of 50 and 75 ohm RF connectors, so small that all of the twenty-two connectors in the series easily fit in the palm of your hand!—the ruler certainly tells the story of the amazing new AMPHENOL **subminax** RF connectors! A result of the continuing AMPHENOL development work in the field of miniaturization, the new **subminax** connectors have all the dependable features of their older, larger brothers compressed into a fraction of the space usually demanded in RF connectors!

The **subminax** line is exceptionally complete. Connectors are available in both screw-on and push-on types in either 50 or 75 ohms. In each design there is a plug, jack, receptacle, jack bulkhead and feed through. In addition, *hermetically sealed* receptacles are available in the 50 ohm and 75 ohm screw-on connectors. Construction? **Subminax** connectors have machined brass bodies with a tough and shining gold-plated finish.

Although **subminax** cable assemblies are available directly from AMPHENOL, assembly at your plant is both easy and practical. Inexpensive and easy-to-use *hand crimpers* are available along with the necessary lengths of AMPHENOL Miniature Coaxial Cable.



### 50 ohm Push-on

| Part No. | Description |
|---|---|
| 27-1 | Plug |
| 27-2 | Jack |
| 27-3 | Receptacle |
| 27-4 | Jack Bulkhead |
| 27-5 | Feed Through |

### 50 ohm Screw-on

| Part No. | Description |
|---|---|
| 27-5 | Plug |
| 27-8 | Jack |
| 27-9 | Receptacle |
| 27-10 | Jack Bulkhead |
| 27-11 | Feed Through |
| 27-12 | Receptacle, Hermetically Sealed |

### 75 ohm Push-on

| Part No. | Description |
|---|---|
| 27-13 | Plug |
| 27-14 | Jack |
| 27-15 | Receptacle |
| 27-16 | Jack Bulkhead |
| 27-17 | Feed Through |

### 75 ohm Screw-on

| Part No. | Description |
|---|---|
| 27-19 | Plug |
| 27-20 | Jack |
| 27-21 | Receptacle |
| 27-22 | Jack Bulkhead |
| 27-23 | Feed Through |
| 27-24 | Receptacle, Hermetically Sealed |

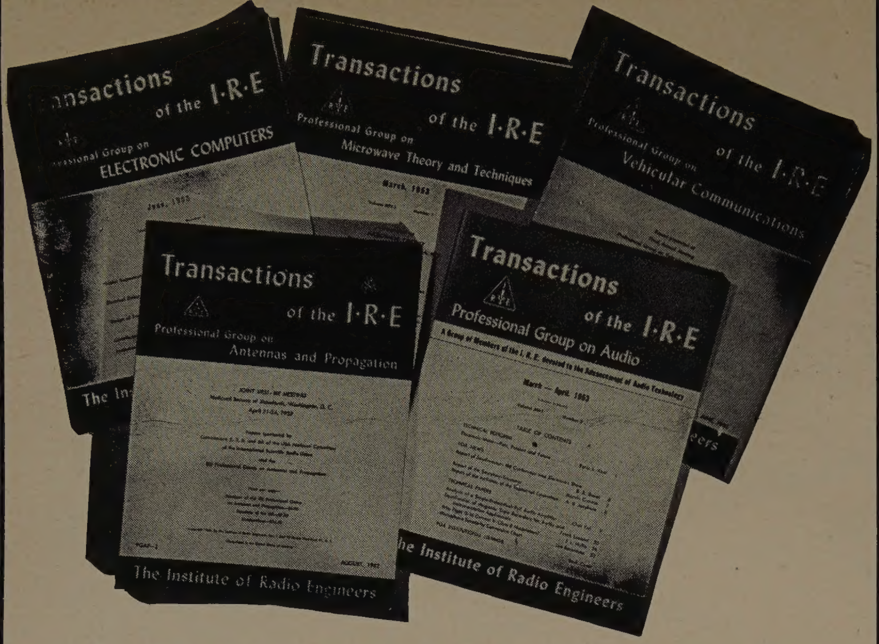
### MINIATURE COAXIAL CABLE

Three types of miniature coaxial cable are available from AMPHENOL for making *subminax* assemblies. These are 50 ohm and 75 ohm polyethylene dielectric with black vinyl jacket cable and a 50 ohm Kel-F dielectric and Kel-F jacket cable.

| Part No. | RG-/U No. | Impedance | Description |
|---|---|---|---|
| 21-596 | — | 50 ohm | Kel-F |
| 21-597 | — | 75 ohm | Poly. |
| 21-598 | 174 | 50 ohm | Poly. |

AMERICAN PHENOLIC CORPORATION
*chicago 50, Illinois*
*In Canada:* AMPHENOL CANADA LTD., *Toronto*

*depend on*
AMPHENOL
*for progress!*


Transactions of the I·R·E Professional Group on Electronic Computers

Transactions of the I·R·E Professional Group on Microwave Theory and Techniques

Transactions of the I·R·E Professional Group on Vehicular Communications

Transactions of the I·R·E Professional Group on Antennas and Propagation

Transactions of the I·R·E Professional Group on Audio

The Institute of Radio Engineers

# At least one of your interests is now served by one of IRE's 21 Professional Groups

**Each group publishes its own specialized papers in its *Transactions*, some annually, and some bi-monthly. The larger groups have organized local Chapters, and they also sponsor technical sessions at IRE Conventions.**

| | |
|---|---|
| Aeronautical and Navigational Electronics (G 11) | **Fee $2** |
| Antennas and Propagation (G 3) | **Fee $4** |
| Audio (G 1) | **Fee $2** |
| Broadcast & Television Receivers (G 8) | **Fee $2** |
| Broadcast Transmission Systems (G 2) | **Fee $2** |
| Circuit Theory (G 4) | **Fee $2** |
| Communication Systems (G 19) | **Fee $2** |
| Component Parts (G 21) | **Fee $2** |
| Electron Devices (G 15) | **Fee $2** |
| Electronic Computers (G 16) | **Fee $2** |
| Engineering Management (G 14) | **Fee $1** |
| Industrial Electronics (G 13) | **Fee $2** |
| Information Theory (G 12) | **Fee $2** |
| Instrumentation (G 9) | **Fee $1** |
| Medical Electronics (G 18) | **Fee $1** |
| Microwave Theory and Techniques (G 17) | **Fee $2** |
| Nuclear Science (G 5) | **Fee $2** |
| Reliability and Quality Control (G 7) | **Fee $2** |
| Telemetry & Remote Control (G 10) | **Fee $1** |
| Ultrasonics Engineering (G 20) | **Fee $2** |
| Vehicular Communications (G 6) | **Fee $2** |

IRE Professional Groups are only open to those who are already members of the IRE. Copies of Professional Group Transactions are available to non-members at three times the cost-price to group members.

**The Institute of Radio Engineers**
**1 East 79th Street, New York 21, N.Y.**

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PG 12-54

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New York 21, N.Y.

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# *Professional Group on Nuclear Science*

The growth of the radio engineering field over the past decade has been remarkably rapid and shows every indication of continuing in rather spectacular fashion for many decades to come. Much of the progress to date has been in the development of new and improved means of communications. However, the progress of the future promises to be more and more in the application of radio and electronics in areas outside the communications field.

On October 6 and 7 of this year in Chicago, the IRE Professional Group on Nuclear Science held its first national annual meeting. The significance of this event goes considerably beyond the meeting itself, for it points up the fact that the future is upon us and that already radio engineering is finding important applications in "non-radio" fields. It is significant also that this field of the future is already being served by an active IRE Professional Group.

The Nuclear Science Group had its beginnings shortly after the war when the IRE formed a Nuclear Science Committee to provide a forum for those engineers and scientists who worked in the new and rapidly developing field of nuclear technology. The Nuclear Science Committee gave rise to the Professional Group on Nuclear Science, which has now grown to 750 active members, with Chapters in Albuquerque, Boston, Chicago, Connecticut Valley, Dayton, Los Alamos, and Oak Ridge.

In addition to its own annual meeting, the Group has sponsored Electronic Instrumentation in Medicine and Nucleonics and at the IRE sessions at the Annual Conference on National Convention. More recently, it has expanded its activities by commencing publication of a quarterly *Transactions*, devoted to reporting important, recent technical developments and news of interest to its members. This young field is already profiting greatly from the many and expanding activities of the Professional Group on Nuclear Science.

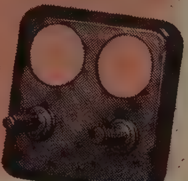
W. R. G. Baker

**Chairman, Professional Groups Committee**

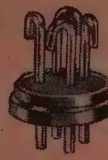
## Got a problem?

This engineer just solved one in a matter of moments with his copy of **Catalog No. 200, Vac-Tite* Compression Multi-Headers:**

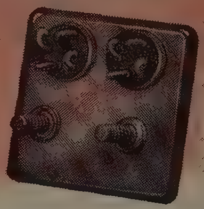
**The Problem:**
4-terminal headers for a cover on a sensitive relay enclosure.



## The solution:



The exact part he needs is found on page 3. **Hermetic** part number MSC 375R-400 EA4 meets the need perfectly with four terminals, hooked outside, straight-cut inside; a flange reversed body, for inside mounting in a plain, pierced, .350 dia. hole.



# FREE! Our New Addition to Your Encyclopedia Hermetica

### Now Available, Hermetic's Catalog No. 200, Offering Unparalled Coverage of Vac-Tite* Compression Multi-Headers.

This handy desk-side reference on compression multi-headers is the latest volume of a series on hermetic seals for electronics "packaging". This series codifies and catalogs every significant innovation in hermetic seals. When complete, we believe you will find the **"Encyclopedia Hermetica"** the easiest, most helpful source of design and purchasing information on hermetic seals available in the industry.

**Hermetic's Catalog No. 200, Vac-Tite* Compression Multi-Headers,** lists over 2,500 separate variations in body constructions, sizes and terminations. This wide selection is codified and arranged in an easy tabular form so that selection is almost automatic. When using this catalog, almost any conceivable preferred type of multi-header can be located and identified by its exact **Hermetic** number in a matter of seconds.

You will find a copy of this latest volume of the **"Encyclopedia Hermetica"** a most useful desk-side aid in selecting the exact multi-header you need—why not write today for your free copy?

***Vac-Tite**—a major improvement in mechanical strength and rigidity, achieved by **Hermetic's** exclusive glass-to-metal chemically bonded compression construction.

compression
multi-headers
Hermetic Seal Products Co.

# Hermetic Seal Products Co.

29 South Sixth Street, Newark 7, New Jersey

FIRST & FOREMOST IN MINIATURIZATION

SEALED IN by HERMETIC HEADERS

New hf wave analyzer!

Sierra 158 High Frequency Wave Analyzer

Fast, convenient, 500 KC to 10 MC!

New Sierra 158 Analyzer is a highly selective, double superheterodyne receiver providing wave analysis data direct in dbm referred to 600 ohms impedance. The instrument uses a cathode follower input probe with two detachable capacity dividers for 20 or 40 db attenuation. It also includes a built-in attenuator adjustable in 10 db steps to a maximum of 60 db. These features, in combination with 22 db usable meter readings, provide a measurement range of 122 db, from —80 to +42 dbm. A measurement accuracy of ±2 db is assured for levels above —70 dbm. Spurious components from analyzer circuits are at least 50 db below fundamental. An injection oscillator at 2 mc is provided for rapid voltage calibration. A phone jack is available for aural monitoring. The instrument also includes the Sierra-designed precision spiral-scale frequency dial. *Write for complete data.*

SPECIFICATIONS

**Frequency Range:** 0.5 to 10 megacycles.

**Signal Measurement Range:** —80 dbm to +42 dbm, referred to 600 ohms. (77.5 μv to 97.5 v)

**Selectivity:** 3 db down at 3 kc off; 30 db down at 12 kc off.

**Signal Measurement Accuracy:** ±2 db above —70 dbm.

**Spurious Responses:** At least 50 db down.

**Input Impedance:** Greater than 1 megohm shunted by approximately 8 μμf.

**Frequency Calibration Accuracy:** Depends on stability and calibration accuracy of the 22.5 - 32 mc variable oscillator, which is maintained within 0.25%. This results in dial accuracy ranging from ±.056 mc to ±.080 mc.

**Operating Power Requirements:** 105 to 125 volts, 50/60 cps, 95 watts drain.

**Cabinet Dimensions:** 17 inches wide, 9$\frac{1}{16}$ inches high, 13½ inches deep.

**Weight:** Approximately 40 pounds.

*Data Subject to Change Without Notice*

Sierra

Sierra Electronic Corporation
San Carlos 2, California, U.S.A.
*Sales representatives in major cities*

Manufacturers of Carrier Frequency Voltmeters, Wave Analyzers, Line Fault Analyzers, Directional Couplers, Wideband RF Transformers, Custom Radio Transmitters, VHF-UHF Detectors, Variable Impedance Wattmeters, Reflection Coefficient Meters.

3235

## Industrial Engineering Notes*

### FEDERAL PERSONNEL

**Announcement has been made of the resignation of Federal Communications Commissioner George E. Sterling.** William A. Porter is resigning as Assistant Director of the Office of Defense Mobilization in Charge of Telecommunications. Harold M. Botkin, former staff director of the Communications Division, Office of Transportation and Communications, Department of Defense, is slated to replace Mr. Porter. Mr. Sterling's resignation, after 30 years of government service, was prompted by advice from his physician, he said. He was named to the Commission in 1947, succeeding E. K. Jett to a term that expired June 30, 1950. His present term expires in June 1957. In 1923, Mr. Sterling entered government service as a radio inspector in the Bureau of Navigation, Department of Commerce. With the formation of the Federal Radio Commission he moved to that agency and in 1934 joined its successor, the FCC. He worked in many positions with the agency and prior to his appointment to the commission was the FCC's Chief Engineer. . . . **George C. McConnaughey** has been sworn in as a new member and chairman of the Federal Communications Commission. His recess appointment to fill the unexpired term of George E. Sterling was announced at the summer White House in Denver. At the same time, President Eisenhower named Mr. McConnaughey as FCC Chairman to succeed Rosel H. Hyde who has served as Acting Chairman since his one-year term in that post expired on June 30. Mr. Hyde remains, at least for the present, as a member of the Commission.

### FCC ACTIONS

**The Federal Communications Commission has approved a temporary CONELRAD plan, to be complied with voluntarily by all stations** (except AM, FM, TV, amateur, and aviation) **operating on frequencies up to 890 mc, until final mandatory plans are put into effect.** The plan is being directed to licensees in the following radio services: international noncommercial educational FM, experimental and auxiliary broadcast, experimental, public radio communication, maritime stations on land, maritime mobile stations on shipboard, public safety, industrial, land transportation, and disaster communications. The plan is to be used only in the event of an actual radio alert and only until approved mandatory plans and regulations are completed and officially put into operation for these services. Copies of the voluntary CONELRAD plan as it applies to the services mentioned above will be furnished upon individual request to the Federal Communications Commission, Washington 25, D. C.

*(Continued on page 56A)*

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* The data on which these NOTES are based were selected by permission from *Industry Reports*, issues of September 20 and 27, October 4, published by the Radio-Electronics-Television Manufacturers Association, whose helpfulness is gratefully acknowledged.

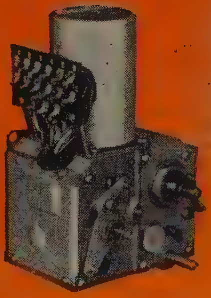
# In automatic positioning

# *Collins* AUTOTUNE*

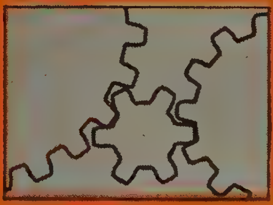
# leads the field

**Select the channel**

**to Activate Autotune**



**Your Mechanism is Positioned**



The Collins AUTOTUNE* is the standard of the world in automatic positioning systems. Its superior performance has been proven for both remotely and locally controlling automatic tuning of high quality military and commercial communication equipment. Collins AUTOTUNE is also applied to many other equipments which require precision positioning.

The system can be actuated by either a remote or local selector switch having one position for each selector channel. Settings on any selector channel can be changed in a few seconds, giving the operator complete re-set control.

Standard AUTOTUNE heads — both Single-turn and Multi-turn — are available to industry. The Type 496A packaged unit illustrated is an example of a particularly compact AUTOTUNE system for use where minimum weight and space allocations exist. It has a re-set accuracy of 0.05 angular degrees which means approximately **1/10,000 inch** on a quarter inch diameter shaft.

Write for complete information, or advise us of your design problems. We are confident that we can supply an AUTOTUNE to meet your positioning requirements.

*Registered U. S. Patent Office

**COLLINS RADIO COMPANY**
Cedar Rapids, Iowa,

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1930 Hi-Line Drive, DALLAS 2
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**Send this coupon for a fully descriptive, 16-page brochure on Collins AUTOTUNES.**

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Gentlemen: Please send me your 16-page brochure on Collins Autotunes.

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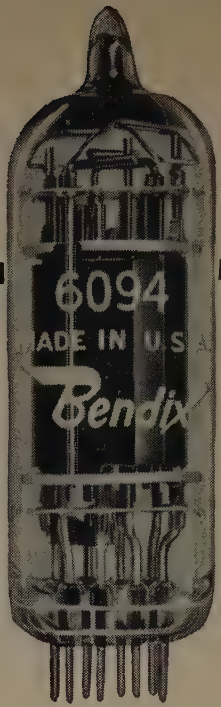

**Where dependability, long life and uniform performance are all-important . . . select**

**Bendix Red Bank**

ECLIPSE

**HARD GLASS Miniature Beam Power Amplifier**

Here's another advance in the Bendix Red Bank "Reliable" Vacuum Tube program. Featuring a hard glass bulb and stem with gold-plated pins . . . plus a conservative design center of cathode temperature . . . the Bendix Red Bank RETMA 6094 can operate at temperatures up to 300° C. compared to an average of only 175° C. for soft glass bulbs. Thus, this new tube ideally meets aircraft, military and industrial applications where freedom from early failure, long service life, and uniform performance are essential.

The Bendix 6094 uses pressed ceramic spacers, instead of mica, for element separation. In other tubes, deterioration of mica in contact with the hot cathode causes loss of emission which is greatly accelerated under shock and vibration. Ceramic eliminates this problem and greatly reduces damage caused by fatigue failure of parts.

For complete details on our special-purpose tubes, write today.

**ELECTRICAL RATINGS***

| | |
|---|---|
| Heater voltage (AC or DC)** | 6.3 volts |
| Heater current | 0.6 amps. |
| Plate voltage (maximum DC) | 275 volts |
| Screen voltage (maximum DC) | 275 volts |
| Peak plate voltage (max. instantaneous) | 550 volts |
| Plate dissipation (absolute max.) | 12.5 watts |
| Screen dissipation (absolute max.) | 2.0 watts |
| Cathode current (max. instantaneous peak value) | 100.0 ma |
| Heater-cathode voltage (max.) | ±450 volts |
| Grid resistance (max.) | 0.1 megohm |
| Grid voltage (max.) | +5.0 volts |
| (min.) | −200.0 volts |
| Cathode warm-up time | 45 seconds |

(Plate and heater voltage may be applied simultaneously.)

*To obtain greatest life expectancy from tube, avoid designs where the tube is subjected to all maximum ratings simultaneously.

**Voltage should not fluctuate more than ±5%.

**MECHANICAL DATA**

| | |
|---|---|
| Base | 9 pin miniature hard glass—gold plated tungsten pins |
| Bulb | Hard glass—T6½ |
| Max. over-all length | 2⅞" |
| Max. seated height | 2⅝" |
| Max. diameter | ⅞" |
| Mounting position | any |
| Max. altitude | 80,000 feet |
| Max. bulb temperature | 300°C. |
| Max. impact shock | 500g |
| Max. vibrational acceleration | 50g |

(100-hour shock excited fatigue test, sample basis.)

**Bendix Red Bank**

ECLIPSE

*Manufacturers of Special-Purpose Electron Tubes, Inverters, Dynamotors, Voltage Regulators, Fractional D.C. Motors and A.C. and D.C. Generators.*

EATONTOWN, N. J.

DIVISION OF Bendix AVIATION CORPORATION — THE NAME MILLIONS TRUST

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Export Sales: Bendix International Division, 205 E. 42nd St., New York 17, N. Y.
Canadian Distributor: Aviation Electric Ltd., P.O. Box 6102, Montreal, P.Q.

# Industrial Engineering Notes

(Continued from page 50A)

. . . **The Federal Communications Commission has announced that, effective immediately, it will issue no further VHF Shoran authorizations.** The commission advised existing licensees now authorized to use the frequencies in the band 225–328.6 mc, in connection with the operation of Shoran equipments, that new authorizations or renewals of existing authorizations will be made only after Dec. 31, 1954, unless by such time provision has been made in the rules to permit the use of those frequencies by non-government stations.

TECHNICAL

**The Office of Technical Services, Commerce Department, has listed a number of studies in the field of electronics in its August issue of the "Bibliography of Technical Reports."** The following government-sponsored research reports can be purchased from the Photoduplication Section, Library of Congress, Washington 25, D. C., for the reported price: "Waveguide Slot Arrays of Large Squint Angle," PB 114204, microfilm, $3.25; photocopy, $9. "Seismic Model Study of Refractions from a Layer of Finite Thickness," PB 113607, microfilm, $2.25; photocopy, $4. "Propagation of Alfven Waves Through the Ionosphere," PB 114281, microfilm, $2.25; photocopy, $4. "Use of Radar in Weather Forecasting with Particular Reference to Radar Set AN/CPS-9," PB 114097, microfilm, $3.75; photocopy, $10.25. "Diffusion of a Plasma Across an Inhomogeneous Magnetic Field," PB 114189, microfilm, $2; photocopy, $2.25. "Instruction Manual on Equivalent Circuit Measurements of Waveguide Structures," PB 113880, microfilm, $9.25; photocopy, $40.25. "New Shunt Technique for Microwave Measurements," PB 114107, microfilm, $2.25; photocopy, $4. "On Evaluation of Solutions to Equations of Wave Propagation in a Layered Half-Space," PB 114280, microfilm, $2.25; photocopy, $4. "Measurements of Materials with High Dielectric Constant and Conductivity at Ultra High Frequencies," PB 113997, microfilm, $2; photocopy, $2.75. "Dependence of Total Microwave Atmospheric Absorption on Propagation Path Elevation," PB 114048, microfilm, $3; photocopy, $7.75. "Back Scattering from Wide-Angle and Narrow-Angle Cones," PB 113625, microfilm, $2.75; photocopy, $6.50. "Autocorrelogram of Randomly Fading Waves with Applications to Wind Measurements at 150 Kc/S," PB 114317, microfilm, $2.50; photocopy, $5.25. "Protective Coatings for Microwave Antennas—Final Report," PB 114098, microfilm, $3.25; photocopy, $9. "Electrical Losses in Ceramic to Metal Seals," PB 114049, microfilm, $2.75; photocopy, $6.50. "Application of Magnetic Amplifiers in the Audio-Frequency Range," PB 114120, microfilm, $5; photocopy, $15.25. "Application of Side-Tone in Subjective Tests of Microphones and Headsets," PB 114247, micro-

(Continued on page 59A)

## Industrial Engineering Notes

*(Continued from page 56A)*

film, $1.50; photocopy, $1.50. "Methodological Study of Electronics Trouble Shooting Skill: I. Rationale for and Description of the Multiple-alternative Symbolic Trouble Shooting Test," PB 113940, microfilm, $2.75; photocopy, $6.50. "Ionosphere Propagation Research. Technical Report No. 1," PB 113979, microfilm, $3.75; photocopy, $10.25. "Low Frequency Propagation Studies. Quarterly Technical Report No. 1," PB 113101, microfilm, $2.25; photocopy, $7.50. "Polarization of Radio Waves Reflected from the Ionosphere at Nonvertical Incidence. II: Measurement Techniques and Experimental Results," PB 114313, microfilm, $4.75; photocopy, $14. "Spherical Transmission Line Approach to the Calculation of Radiation Conductances," PB 114045, microfilm, $3.25; photocopy, $9. "Variational Approximations to the Diffraction by Circular and Elliptical Apertures," PB 113311, microfilm, $2.75; photocopy, $6.50. . . . **The Bartlett and Reed Management Co., Rapid City, S. D., has filed applications with the FCC covering an experimental microwave relay system extending from Granite Canyon, Wyo., to Rapid City and designed to serve prospective community antenna television systems in Rapid City.** Seven stations are proposed, the applicant stated, and the total estimated cost of the project will be $211,265, of which $187,813 is for equipment. Under proposed charges, the company will run approximately $40 per airline mile per month, or $8,500 per month to the customer at Rapid City. This compares, according to the applicant, to the $60 a month per airline mile now being charged by the Bell System. Monthly subscription charges are estimated to be approximately $7.50. Charges for services will be on a package basis, including both video and audio services in one rate. Rapid City and the Black Hills area is not served by any TV system and the grant of the applications will bring to the area network and local TV programs now available in the Denver area. . . . **The University of California Press, Berkeley, Calif., has printed and released the Navy Electronics Laboratory's handbook on human engineering.** The publication, "NEL Human Engineering Guide," reportedly will be of considerable value to electronic design engineers in that it sets forth the principles of design which are necessary to make equipment compatible with human capabilities. . . . **Research on application of semiconducting diodes has led the National Bureau of Standards to the development of a new class of amplifiers that utilizes the reverse transient phenomenon of these two-element rectifying devices.** The diode amplifier, devised by A. W. Holt, uses no vacuum tubes and achieves power gains up to 10 per stage, thus promising important application in the future design of high-speed electronic digital computers. The new diode amplifier, the NBS announced, may

*(Continued on page 60A)*

For greater performance at lower cost . . .

AEROVOX
DURAMIC
AEROVOX
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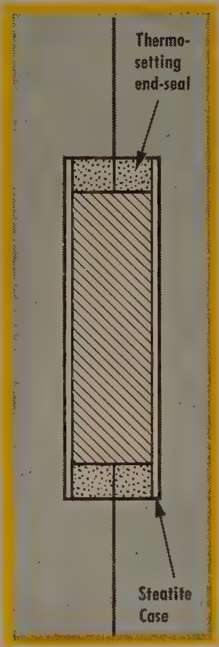
DURAMIC

**DURAMICS***

**AEROVOX Type P84 CM**

**Ceramic-Cased Paper Tubulars**



GET THE FACTS!

FUNCTION FITTED

Ceramic-cased tubulars for engineers and designers seeking performance above that of conventional cardboard tubulars.

Dense steatite casing, with specially-developed end-sealing material, provides exceptional protection against humidity. End-seals firmly adhered to the ceramic tubing, will not soften or flow at any rated temperature. Terminal lead wires will not loosen or pull out even with severe handling.

Operating temperature range of from —55°C to +85°C. Life test for Type P84 CM Duramics is 1½ times rated voltage at 85°C. for 250 hours. These units meet requirements of RETMA Specification REC-118, high-temperature range, Class M capacitors, and withstand the 250-hour humidity resistance test. Excellent power factor, insulation resistance, temperature-coefficient.

**Ask for Bulletin NPA-200 containing detailed information and standard numbers. Write on business stationery for sample which best tells its own story of superlative performance.**

*TRADE-MARK

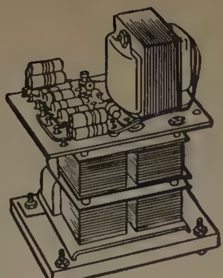
AEROVOX Capacitors

**AEROVOX CORPORATION**
NEW BEDFORD, MASS.

| Hi-Q DIVISION<br>OLEAN, N. Y. | ACME ELECTRONICS, INC.<br>MONROVIA, CALIF. | CINEMA ENGINEERING CO.<br>BURBANK, CALIF. |
|---|---|---|

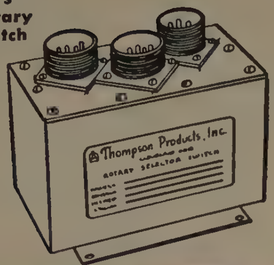
In Canada: AEROVOX CANADA LTD., Hamilton, Ont.

Thompson's
Magnetic
Amplifier



**ideas...**

Thompson's
Airborne Rotary
Selector Switch



**facilities...**

**experience**

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**It's no accident** that more and more manufacturers are turning to Thompson to solve tough electronics problems.

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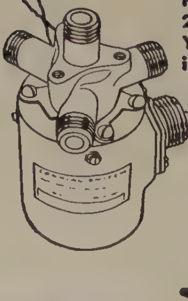
One of the
many
Thompson
Coaxial
Switches



*Electronics Division*

**Thompson Products, Inc.**

2196 CLARKWOOD RD., CLEVELAND 3, OHIO

## Industrial Engineering Notes

(Continued from page 59A)

be used as a pulse repeater stage, in varied types of flip-flop circuits, or as a wide-band, flat-response amplifier. Because suitable diodes are now in regular production, commercial applications reportedly are practical at the present time. Future improvement in the manufacture of diodes may make the principle useful for amplification at even microwave frequencies. The basic requirement of the diode amplifier, whose amplification is not continuous, is that it be supplied with power from an radio-frequency source whose frequency is the same or higher than the modulating signal frequency. This requirement puts the circuit in the same category as magnetic and dielectric amplifiers. Thus, power gain is obtained by a transfer of current from one circuit of low impedance to another circuit of high impedance. This is likened to the way in which amplification is obtained in a transistor. Details on this new diode amplifier will be published in the October issue of the *Technical News Bulletin*, the Bureau's monthly publication.

## Professional Group Meetings

### AERONAUTICAL AND NAVIGATIONAL ELECTRONICS

The Dayton Chapter of the Professional Group on Aeronautical and Navigational Electronics met September 2 at the Engineer's Club. L. Rossoff, of the Radio Receptor Company, Brooklyn, N. Y., spoke on "PNP Alloy Junction Photo Transistors." He discussed recommended circuits, particularly with respect to temperature stabilization of operation. Operating characteristics, both electrical and optical, were displayed together with practical production tolerances.

The New York Chapter met in June at the General Electric Auditorium, and Dr. D. O. McCoy, of Collins Radio, delivered a paper entitled, "A Simplified Omni-Range System for Terminal Navigation." The following officers were elected: Chairman, Robert Bibbero; Vice-chairman, Gordon P. McCouch; Secretary, Philip B. Petersen.

### CIRCUIT THEORY

The Los Angeles Chapter of the Professional Group on Circuit Theory met in September at the Institute for Numerical Analysis Building. W. R. Abbott presided. "Radar," was the subject of a paper by R. S. Julian, head of the electronics department of the guided missile division, Hughes Aircraft Company. F. Carver, head of the radar and development section of Hughes Aircraft, spoke on "Some Typical Radar Transmitter Design Problems and Their Solutions."

(Continued on page 62A)

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Eimac
TUBES

# Eimac HR Connectors

## HEAT TRANSFERRING ELECTRICAL CONNECTORS FOR EIMAC TUBE TYPES

Eimac HR connectors are especially designed to give proper electrical connections with the plate and/or grid terminals of Eimac tube types while providing efficient transfer of heat to the air from the tube element and glass seal. Machined from solid dural rod, these heat radiating connectors are available in ten types to accommodate Eimac internal anode type tubes — rectifiers, triodes, tetrodes or pentodes.

*For further information on Eimac HR connectors, contact our Application Engineering department.*

Eimac

**EITEL-McCULLOUGH, INC.**
**SAN BRUNO, CALIFORNIA**
**The World's Largest Manufacturer of Transmitting Tubes**

## Professional Group Meetings

*(Continued from page 60A)*

COMPONENT PARTS

The Dayton Chapter meet on September 2 at the Dayton Engineers Club. Philip Ohmart, president of Ohmart Corporation, delivered a paper called "The Nuclear Cell." F. E. Wenger presided.

With R. R. W. Lacy presiding, the Los Angeles Chapter met at the Aeronautical Sciences Building on September 13. Norman Swartz, of Southern Electronics Company, spoke on "Precision Capacitors," and Gustave Geiger, of IRCAL Industries, spoke on "Precision Resistors." A question and answer period was held at the end of each talk.

The Washington Chapter met on September 15 at the Manse Lecture Room, National Bureau of Standards. Gustave Shapiro presided. Norman Doctor, of Diamond Ordnance Fuse Laboratories, spoke on non-linear resistors. Discussion followed.

ENGINEERING MANAGEMENT

The Boston Chapter of the Professional Group on Engineering Management met in September at the Faculty Club of M.I.T. R. I. Cole, of Melpar Inc., spoke on "New Look at Engineering Management." He discussed the guidance that management must provide to ensure healthy growth of its organization.

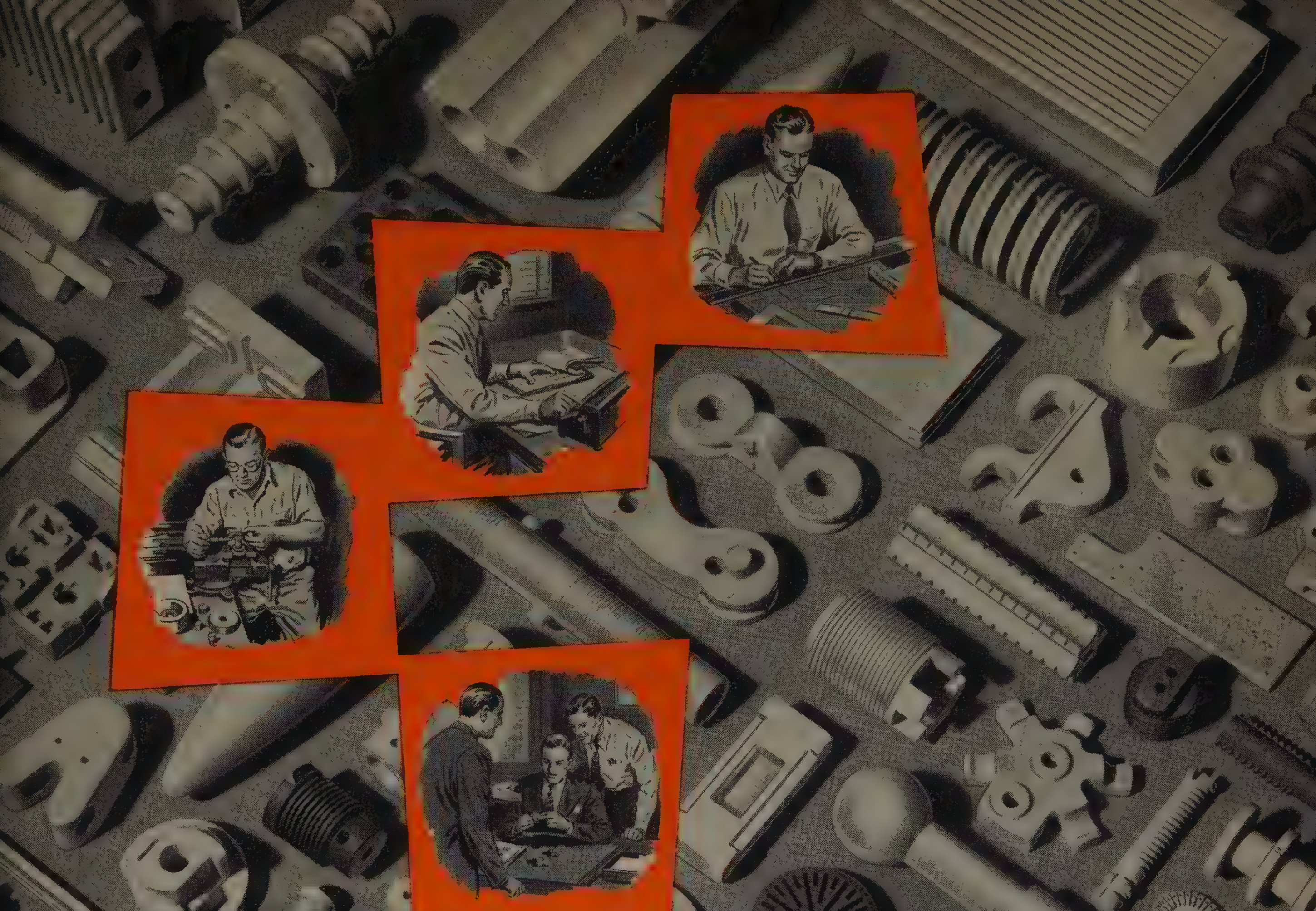
On September 2 the Dayton Chapter met; L. P. Richmond, the Vice-chairman, was in charge. P. R. Marvin, Vice-president of the Commonwealth Engineering Corporation, spoke on "How the Engineer Looks at Management and How Management Looks at the Engineer." Dr. Marvin developed a general outline of the concepts of management. During the discussion that followed, he pointed out that it is not practical for a man to be trained in pure management, independent of some job skill, since lower management levels must have a knowledge of the work being supervised. He said that the levels at which pure management is effective, if ever, are not usually open to young graduates.

NUCLEAR SCIENCE

The Atlanta Chapter met in September at the Ridge Recreation Hall with H. E. Walchli presiding. Dana M. Collier, of the Oak Ridge National Laboratory, spoke on semi-conductors and transistors. With a tinkertoy model of a crystal, showing electron bonds, he discussed the concept of holes and electrons and the effect of groups 3 and group 5 impurities on the crystal. He then discussed the mechanism of semi-conductor diodes and certain limitations of transistors. Typical examples of diodes and transistors were displayed.

On June 16 the Atlanta Chapter had as its speaker William Keating, of the Ford Instrument Company. Discussing magnetic amplifiers, he described the fundamentals and circuits of magnetic amplifiers. The saturable reactor, self-saturable circuit, and the half-wave bridge were shown and discussed.

*(Continued on page 64A)*



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Exclusive 2-speed, inside-out Hysteresis synchronous motor. Direct capstan drive.

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## Professional Group Meetings

*(Continued from page 62A)*

At the May meeting of the Atlanta Chapter W. L. Cisler, of Detroit Edison Company, spoke on "The Future Outlook of Atomic Power Supplies." Alvin Weinberg, and Sam Sapirie, both of Oak Ridge National Laboratory, spoke briefly. About 200 people attended the meeting.

The Chicago Chapter met on October 22 at the Western Society of Engineers Auditorium. Dr. D. H. Loughridge, dean of the Technological Institute at Northwestern University, spoke on "The Present Status of Nuclear Power Development." He discussed ways in which the new atomic energy law allows greater freedom for the development of nuclear power. A review of current programs in industry and government, he said, allows conservative opinion to predict that by 1960 there will be competitive nuclear power plants in operation in relatively high cost power areas in this country.

### Radio Telemetry and Remote Control

The Los Angeles Chapter, with R. E. Rawlins presiding, met in September at the IAS Building. There were three speakers. R. E. Anderson, Stanford Research Institute, spoke on "A Multiple Telemetering Antenna System for Supersonic Aircraft." Irwin Wunderman, Lockheed Aircraft Corporation, spoke on "Optimum Signal-to-Noise Region for Junction Transistors." A. W. Newberry outlined telemetering activities at the California Institute of Technology, Jet Propulsion Laboratories.

### Vehicular Communications

The Detroit Chapter met in May at the Engineering Society of Detroit. C. J. Heller, of Detroit Checker Cab Company, described Checker's 900 cab fleet, of which 700 are now radio equipped with Link equipment. The system is designed to handle 25,000 calls per day. Adequate coverage without excessive overlap of area, Mr. Heller said, has been solved by use of appropriate antennas designed and placed by experimentation, since measured antenna patterns differ widely from published data.

## Section Meetings

### Akron

"Color Television," by A. Pape, Motorola, Inc.; September 21, 1954.

### Atlanta

"A Tutorial Discussion of Radiation Phenomena and Antenna Currents," by W. B. Wrigley, Georgia Institute of Technology; October 1, 1954.

### Beaumont-Port Arthur

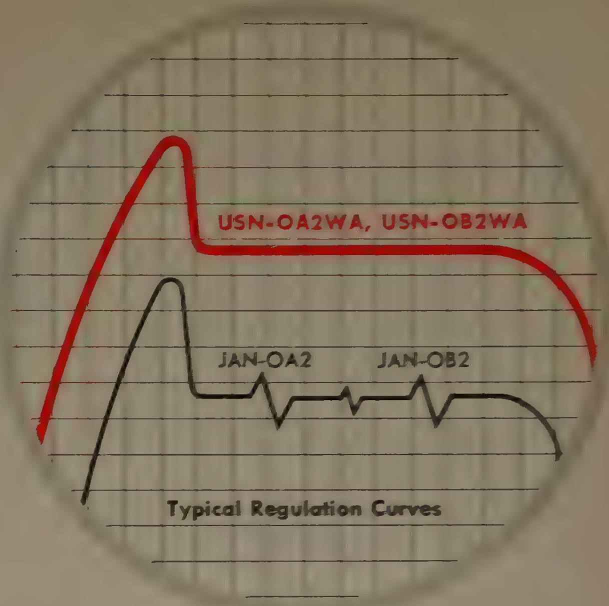
"Some Problems of UHF Stations," by F. R. Leins, KBMT; October 12, 1954.

*(Continued on page 66A)*

# NOW . . . VR TUBES WITHOUT "PIPS"!

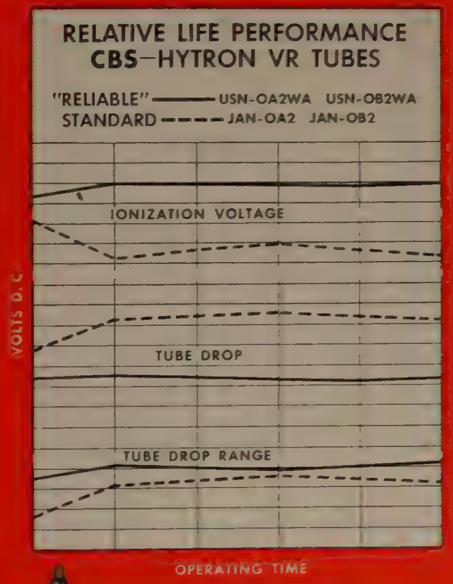
# . . . for Stable Voltage Reference

## NEW "RELIABLE" . . . DUAL-PURPOSE CBS-HYTRON USN-0A2WA USN-0B2WA*

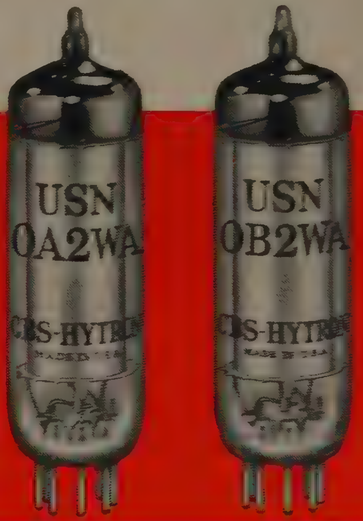


CBS-Hytron, the leader in VR tubes, has solved the "unsolvable" VR-tube problem. Has taken those annoying "pips" (sudden discrete voltage shifts) out of two new CBS-Hytron VR developments: The dual-purpose USN-OA2WA and USN-OB2WA. Both are superior, "reliable" voltage regulators. Both also achieve stable voltage-reference performance.

These new tubes are directly interchangeable with the JAN-OA2 and JAN-OB2. But they are manufactured and tested to new, more rigid U. S. N. Bureau of Ships specifications. USN-OA2WA and USN-OB2WA are designed for dependability under severe environmental conditions . . . and for a wide range of applications. Improved construction and tight quality control offer many advantages. Check features, curves, and construction of these versatile tubes.

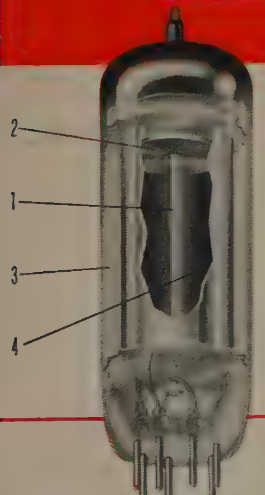


*Improved tubes, tested to U. S. N. specifications, not to be confused with earlier JAN "reliable" versions.*



### CHECK THESE FEATURES

1. Flat, smooth voltage-current characteristic.
2. Greatly improved voltage repeatability.
3. Stable electrical characteristics.
4. Tested under severe conditions of shock, vibration, temperature, and altitude.



### IMPROVED CONSTRUCTION
### USN-0B2WA

Note these improvements: 1. New, simplified aluminum-rod anode. 2. New disc-type starting electrode, to minimize gap-spacing variations and give more uniform starting voltage. (In USN-0A2WA, this electrode is located at bottom of mount assembly.) 3. New gas fill with neon body and low argon content. 4. New composite nickel-aluminum cathode work surface. Improvements 3 and 4 make possible operation at 150°C . . . and stable voltage-reference applications.

**FREE DATA** for both USN-OA2WA and USN-OB2WA. Write for Bulletin E-235.

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**MULTI-(to 60) CHANNEL RECORDING OSCILLOGRAPHS**
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**AMPLIFIER SYSTEMS**
(Model 119)

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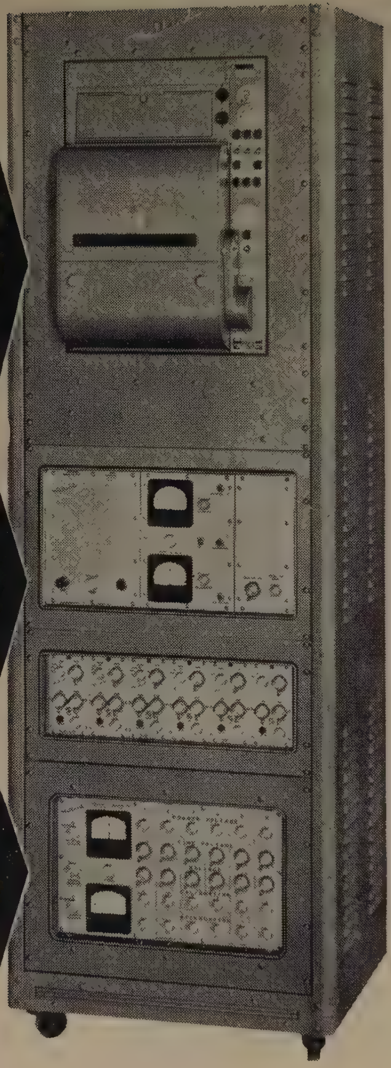
(Model 82-6)



... *designed* **for fixed or mobile relay rack mounting**

Write for complete details on the instruments shown above, as well as portable recording oscillographs and galvanometers.

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## Section Meetings

(*Continued from page 64A*)

BINGHAMTON

"Radio Studies of the Sun," by W. L. Roberts, Westinghouse Electric Corp.; September 27, 1954.

"Cooling of Electronic Equipment," by J. P. Welsh, Cornell Aeronautical Labs.; October 18, 1954.

BUFFALO-NIAGARA

"Microwave Systems Engineering," by B. M. Ray, Westinghouse; September 15, 1954.

CEDAR RAPIDS

Conference on Communications; September 16 and 17, 1954.

CENTRAL FLORIDA

"A Radioactive Battery Exited Electrostatic Generator for Nuclear Radiation Monitoring," by Dr. M. J. Cohen, Radiation Research Corp.; September 23, 1954.

CINCINNATI

Film, "The Baldwin Company" and program "Jazz vs. the Classics"; September 21, 1954.

CLEVELAND

"Observations on the Broadcast Industry," by George Brown, RCA Oabs.; September 24, 1954.

DALLAS-FT. WORTH

Demonstrations of Color Television by R. C. Stinson, Station WBAP; September 17, 1954.

Film, "IBM Digital Computers" and talks, "Digital Computers," by H. S. Wolanski and "Analogue Computers," by D. J. Simmons, both of Convair; September 28, 1954.

DAYTON

"Aspects of Radar Reliability," by A. S. Baran, General Electric Company; October 7, 1954.

DENVER

"The Sun and Radio Communications," by Dr. D. H. Menzel, Harvard College; September 10, 1954.

"The Principles of Color Television," by C. N. Hoyler, R.C.A.; October 15, 1954.

DETROIT

"Contouring with Electronic Machine Tools," by N. B. Nichols, Raytheon Manufacturing Company; September 17, 1954.

"An Automatic Telephone Answering Device," by R. A. Miller, Bell Telephone Labs.; October 15, 1954.

ELMIRA-CORNING

"Vehicular Communications," by J. L. Mulligan, Motorola Communications; September 20, 1954.

EL PASO

"Improvements in Transistor Characteristics and Reliability of Transistors in Low Level Audio Applications," by F. M. Ducat, Raytheon Manufacturing Company; September 24, 1954.

EMPORIUM

"Color Television Receiver Design Using Sequential System," by Kenneth Farr, Westinghouse Electric; August 27, 1954.

"Modular Construction of Electronic Equipment," by James Le Van, Sanders Associates, and "Stacked Tubes," by William Wheeler, Sylvania Electric Products, Inc.; August 28, 1954.

"The Direct Conversion of Radioactive Energy into Electrical Energy," by Dr. J. J. Loferski, RCA; September 23, 1954.

FORT WAYNE

"The Iatron Tube," by Dean W. Davis, Farnsworth Electronics; October 7, 1954.

(*Continued on page 68A*)

For hot spots in
miniature equipment...
rely on Mallory
Tantalum Capacitors
MALLORY

At temperatures as high as +175°C and as low as −55°C, Mallory XT Tantalum Capacitors offer thoroughly dependable operation and stable electrical characteristics. Introduced by Mallory after more than ten years of development, these capacitors are the answer to the extreme temperature problems encountered in miniaturized electronic equipment.

Mallory Tantalum Capacitors give excellent life at high temperatures . . . hold stable capacitance and series resistance values. Rated for 175°C, they can also be supplied on special order for ambients up to 200°C. They perform equally well at the opposite end of the temperature band . . . maintaining high stability of capacitance and impedance down to −55°C.

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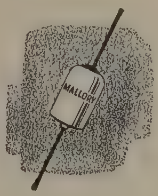
Type TAP tantalum anode capacitors are available in ratings from 6 mfd. 100 volts to 30 mfd. 6 volts, for operation at −55°C to +85°C. Diameter 7/32″; length 3/8″.



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STANDARD MINIATURE

Provide delays ranging from 2 to 120 seconds.

- Actuated by a heater, they operate on A.C., D.C., or Pulsating Current.
  - *Hermetically sealed.* Not affected by altitude, moisture, or other climate changes.
  - Circuits: *SPST only* — normally open or normally closed.

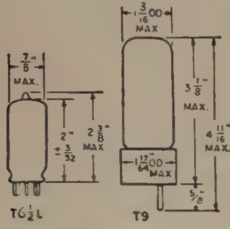
**Amperite Thermostatic Delay Relays** are compensated for ambient temperature changes from —55° to +70°C. Heaters consume approximately 2 W. and may be operated continuously. The units are *most compact, rugged, explosion-proof, long-lived,* and — *inexpensive!*

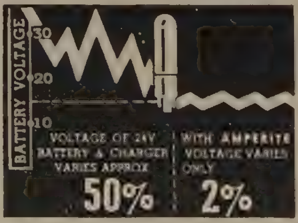
*TYPES:* Standard Radio Octal, and 9-Pin Miniature.

***PROBLEM? Send for Bulletin No. TR-81***

BALLAST-REGULATORS

- Amperite Regulators are designed to keep the current in a circuit ***automatically regulated*** at a definite value (for example, 0.5 amp).
- For currents of 60 ma. to 5 amps. *Operates on A.C., D.C., Pulsating Current.*
- Hermetically sealed, light, compact, and most inexpensive.





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T9 BULB

Maximum Wattage Dissipation: T6½L—5W. T9—10W.

Amperite Regulators are the simplest, most effective method for obtaining ***automatic regulation*** of current or voltage. ***Hermetically sealed,*** they are not affected by changes in altitude, ambient temperature (—55° to +90°C), or humidity. Rugged; no moving parts; changed as easily as a radio tube.

***Write for 4-page Technical Bulletin No. AB-51***

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## Section Meetings

(Continued from page 66A)

HAMILTON

"Color Television," by R. G. Anthes, Canadian Westinghouse Co.; September 13, 1954.

HOUSTON

Fifth Annual Meeting of Professional Group on Vehicular Communications; September 30 and October 1, 1954.

HUNTSVILLE

Tour of Arnold Engineering Development Center, Tullahoma, Tenn.; September 25, 1954.

INYOKERN

Papers on "Instrumentation" presented by Messrs. Howell, Watson, Button, Keene and Shrock all staff members, Air Force Test Center; October 15, 1954.

ITHACA

"Color TV," by Dr. W. R. G. Baker, General Electric Company; October 13, 1954.

LITTLE ROCK

"Well Logging," by R. A. Broding, Century Geophysical Corp.; October 12, 1954.

LONDON

"Factors Affecting the Efficiency of a Modern Steam Electricity Generating Station," by Basil Gill Efficiency Engineer; October 16, 1954.

LONG ISLAND

"X-Band Impedance Plotter," Lecture and Demonstration by H. L. Bachman, Wheeler Labs.; September 22, 1954.

"Operation Research," by Bernard Stowens, Sperry Gyroscope Company; October 13, 1954.

MIAMI

"Atomic Batteries and Their Application of Electrostatic Generators," By Dr. M. J. Cohen, Radiation Research Corp.; September 24, 1954.

MILWAUKEE

"Thermistors and Their Applications," by R. S. Goodyear, Victory Engineering Corp.; September 22, 1954.

NEW ORLEANS

"New Developments in Transistors," by C. R. Dupy, Jr., Southern Bell Tel. and Tel. Co.; September 24, 1954.

NORTH CAROLINA-VIRGINIA

"Telephone Company Radio Relay System," by J. P. Meeham, Cincinnati Div.; September 17, 1954.

NORTHERN NEW JERSEY

"VHF and UHF Television," by Dr. A. B. Glenn, RCA Victor; October 13, 1954.

OTTAWA

"Radar Weather," by Dr. J. S. Marshall, McGill University; October 14, 1954.

PHOENIX

"Electronic Facilities at Sky Harbor Airport," by Kenneth Willits, CAA; September 23, 1954.

PORTLAND

"Physical and Functional Development of Cathode Ray Tubes," by J. Griffith; "Material Development of Cathode Ray Tubes," by Derrol Pennington; and "Production Methods," by John Liedthe, all Development Engineers; September 23, 1954.

Demonstration Lecture on "Color Television," by C. N. Hoyler, RCA; October 20, 1954.

ROME-UTICA

"Ferromagnetic Properties of Ferrites," by Dr. R. Horsch, General Electric Electronics Lab.; October 5, 1954.

(Continued on page 70A)

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# ADVAC HERMETIC SEALS

*Proven reliable in both commercial and military applications including—*

TRANSFORMER TERMINALS, JET ENGINE THERMOCOUPLES, NUCLEONICS, HEATING ELEMENTS, IGNITION INSULATORS, MAGNATRON OUTPUT WINDOWS, VACUUM TUBE CLOSURES, REFRIGERATION COMPRESSORS, SINGLE AND MULTIPLE CONDUCTOR CABLE END SEALS, CHEMICAL INSULATORS, EXPLOSION-PROOF ASSEMBLIES, CAPACITOR TERMINALS, CONNECTORS, RELAYS, FILTERS.

## ..for temperatures to 1400°F ..pressures to 2000 psi

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Metal bands fired to the metalized ceramic surface. Resist amalgamation, will not peel or lift, provide silver surface for soft-soldering.

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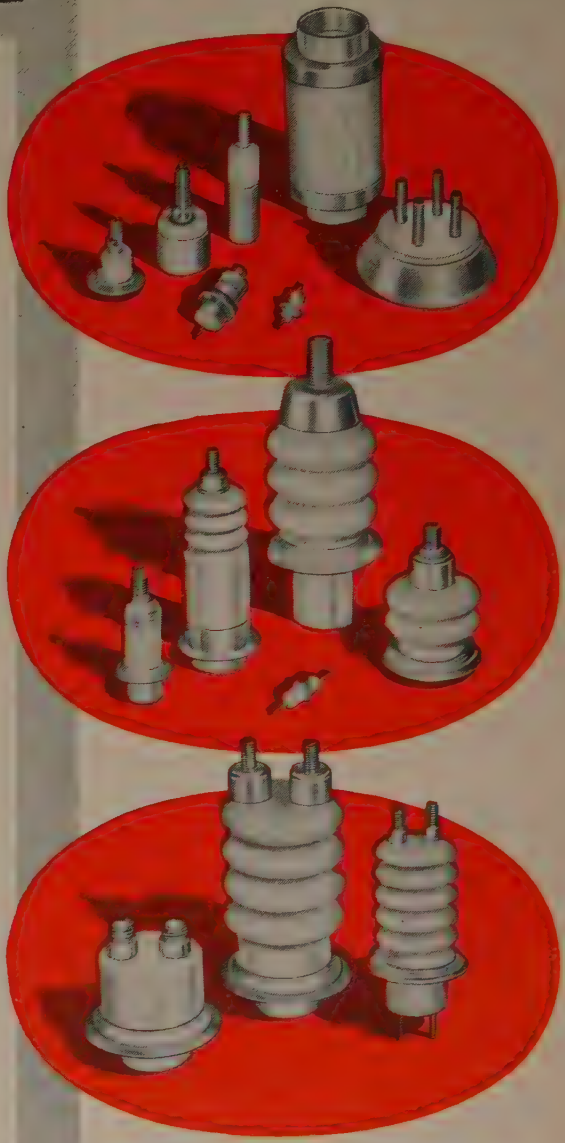
Terminals can be supplied brazed to headers to your specifications. Quotations on complete assemblies, including cover plates, will be furnished on request.

CALL OR WRITE for literature or recommendations on your hermetic sealing problem. ADVAC engineers are specialists in high temperature, high pressure ceramic-to-metal seals. For competent assistance on your particular requirements, contact ADVAC, today!



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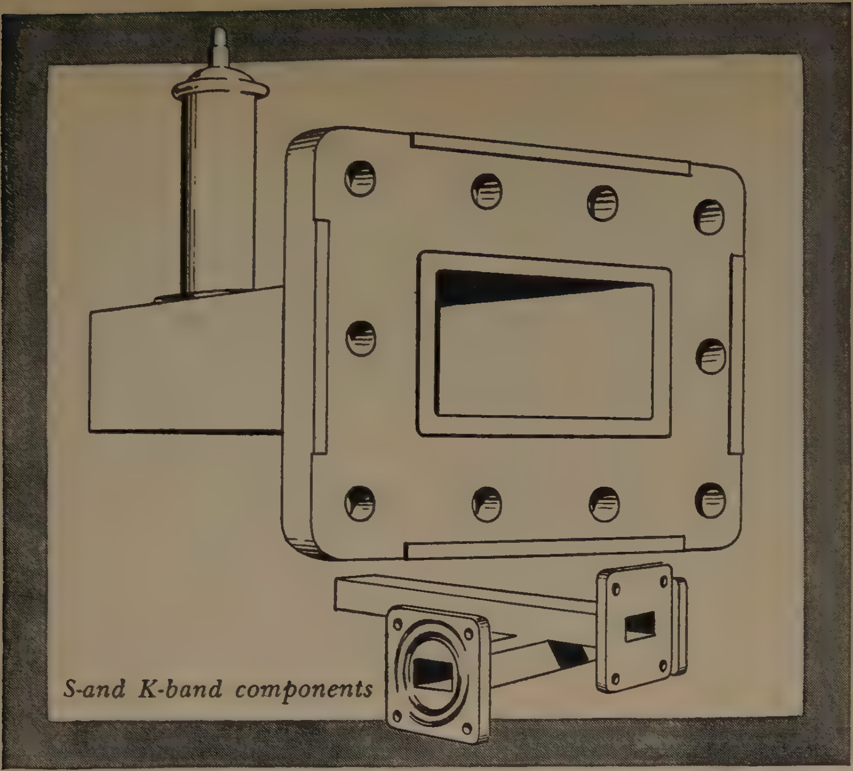
S-and K-band components

how small can a wave guide get?

Well, alongside some of the stuff we're working with now, the radar plumbing we used during World War II gets to look like air-conditioning duct. What's more, some of our boys here seem to regard anything below S-band as practically pure D.C. Naturally, we're up to our hips as usual in work on military equipment. However, we do occasionally have some extra creative capacity available, so if you have a problem involving something special in wave guide components (real small ones, too) and like that, maybe we can help. Drop us a line.

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DESIGN • RESEARCH • PRODUCTION
Microwave Transmission Lines and Associated Components
16 West 61st St. • New York 23, N. Y. • Circle 6-4760
TRADE MARK

## Section Meetings

(*Continued from page 68A*)

SACRAMENTO

"Color Television," by J. H. Wentworth, RCA; October 8, 1954.

ST. LOUIS

"Principles of Color TV," by C. N. Hoyler, RCA; September 15, 1954.

SEATTLE

"Elements of Probability Theory and Engineering Applications," by R. C. McCarty, Boeing Aircraft Company; October 13, 1954.

SYRACUSE

"Electronics in Business and Industry," by W. J. Morlock, General Electric Company; October 18, 1954.

TULSA

"Silicon Transistors and Silicon Alloy Diodes," by Dr. W. A. Adcock, Texas Instrument Co.; September 16, 1954.

TWIN CITIES

"The Factrol System of Machine Tool Control," by John Hogan, The MAICO Co.; September 29. 1954.

VANCOUVER

"Propagation on VHF and Low VHF Channels," by T. D. Cushing, North-West Telephone Company; September 20, 1954.

WASHINGTON, D. C.

"Comparison of Modulation Systems," by Dr. R. M. Page, Naval Research Lab.; October 11, 1954.

WILLIAMSPORT

"Some Aspects of Series String 600 ma. Tubes," by A. W. Peterson, Sylvania Electric Products, Inc.; September 29, 1954.

### *SUBSECTIONS*

AMARILLO-LUBBOCK

Election of officers; September 23. 1954.

BERKSHIRE COUNTY

"Statistical Control of Electronic Manufacturing," by Warren Purcell, Rath & Strong; September 9, 1954.

BUENAVENTURA

"Tracking Filter for Missile Instrumentation," by Louis Katz, Ralph M. Parsons Co.; September 9, 1954.

CHARLESTON

"UHF Television," by R. D. Lambert, Jr., WCOS AM-FM-TV; September 21, 1954.

EAST BAY

"Electronics Research in Europe," by Dr. Sam Silver, University of California; October 18, 1954.

LANCASTER

"The Scintillation Counter," by Dr. G. A. Morton, RCA Labs.; October 13, 1954.

MONMOUTH

"Automation for Electronics," by S. F. Danko and Robert A. Gerhold, both of Signal Corps Engineering Labs.; October 20, 1954.

TUCSON

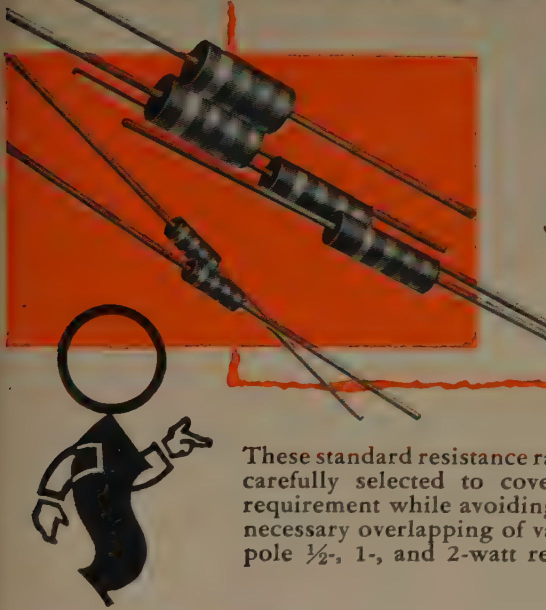
"Noise in Electronic Circuits," by Greg Young, Hughes Aircraft Company; September 27, 1954.

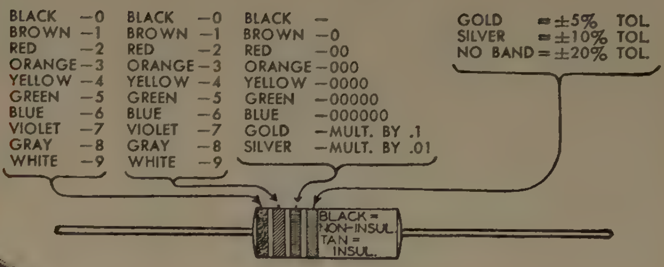
USAFIT

"Outline of Activities Within the Laboratory Regarding Various Phases of Electron Tube Research and Development," by A. Dicke, W-P AFB; October 1, 1954.

# STACKPOLE

# FIXED COMPOSITION RESISTORS




BLACK —0
BROWN —1
RED —2
ORANGE—3
YELLOW —4
GREEN —5
BLUE —6
VIOLET —7
GRAY —8
WHITE —9
BLACK —0
BROWN —1
RED —2
ORANGE—3
YELLOW —4
GREEN —5
BLUE —6
VIOLET —7
GRAY —8
WHITE —9
BLACK —
BROWN —0
RED —00
ORANGE—000
YELLOW —0000
GREEN —00000
BLUE —000000
GOLD —MULT. BY .1
SILVER —MULT. BY .01
GOLD = ±5% TOL.
SILVER = ±10% TOL.
NO BAND = ±20% TOL.
BLACK = NON-INSUL.
TAN = INSUL.

These standard resistance ratings have been carefully selected to cover every circuit requirement while avoiding costly and unnecessary overlapping of values. All Stackpole ½-, 1-, and 2-watt resistors are regularly supplied in each of the ranges and tolerances indicated. Through this standardization you are assured of maximum quality and faster deliveries plus easier stocking of resistors for you.

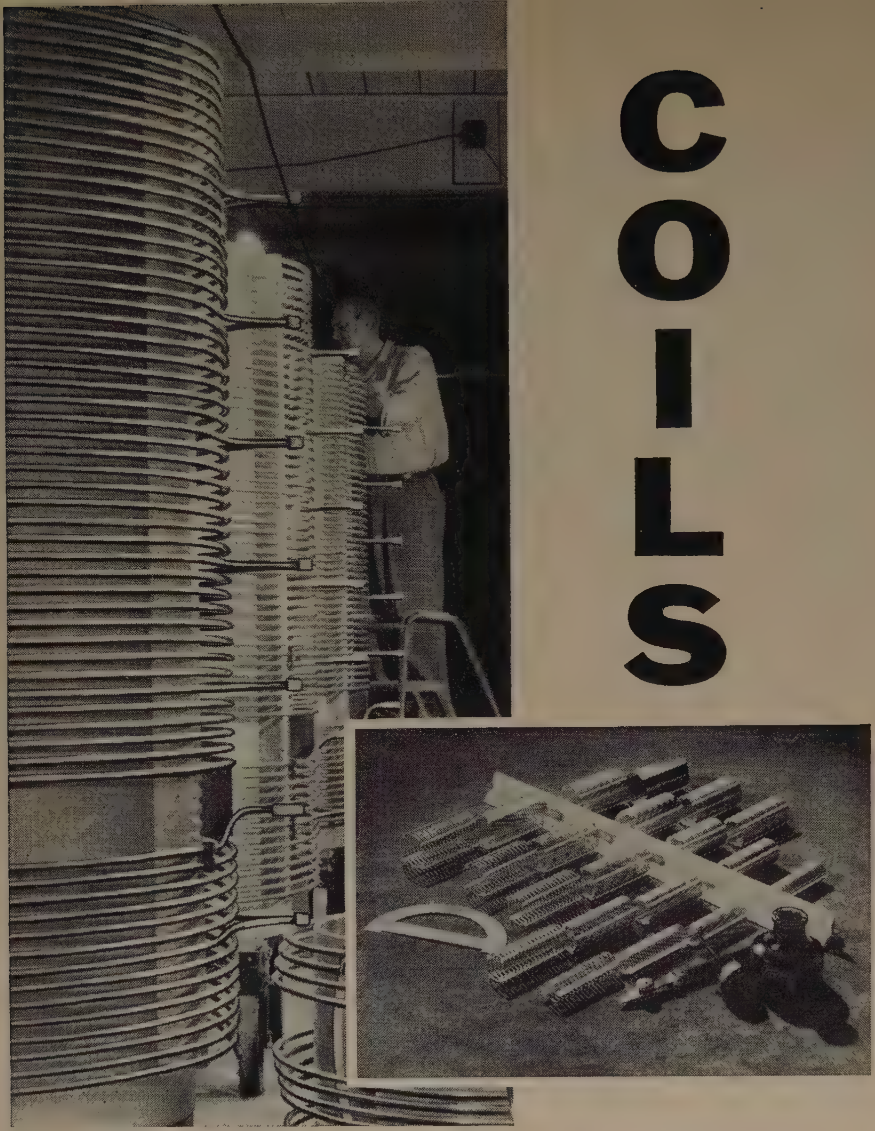
*Electronic Components Division*

**STACKPOLE CARBON COMPANY,** *St. Marys, Pennsylvania*

## These 269 RETMA Values Meet Every Modern Circuit Need!

| ±20% | ±10% | ±5% | ±20% | ±10% | ±5% | ±20% | ±10% | ±5% | ±20% | ±10% | ±5% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 10 | 10 | | 390 | 390 | 15000 | 15000 | 15000 | | 560000 | 560000 |
| | | 11 | | | 430 | | | 16000 | | | 620000 |
| | 12 | 12 | 470 | 470 | 470 | | 18000 | 18000 | 680000 | 680000 | 680000 |
| | | 13 | | | 510 | | | 20000 | | | 750000 |
| 15 | 15 | 15 | | 560 | 560 | 22000 | 22000 | 22000 | | 820000 | 820000 |
| | | 16 | | | 620 | | | 24000 | | | 910000 |
| | 18 | 18 | 680 | 680 | 680 | | 27000 | 27000 | 1.0 Meg | 1.0 Meg | 1.0 Meg |
| | | 20 | | | 750 | | | 30000 | | | 1.1 Meg |
| 22 | 22 | 22 | | 820 | 820 | 33000 | 33000 | 33000 | | 1.2 Meg | 1.2 Meg |
| | | 24 | | | 910 | | | 36000 | | | 1.3 Meg |
| | 27 | 27 | 1000 | 1000 | 1000 | | 39000 | 39000 | 1.5 Meg | 1.5 Meg | 1.5 Meg |
| | | 30 | | | 1100 | | | 43000 | | | 1.6 Meg |
| 33 | 33 | 33 | | 1200 | 1200 | 47000 | 47000 | 47000 | | 1.8 Meg | 1.8 Meg |
| | | 36 | | | 1300 | | | 51000 | | | 2.0 Meg |
| | 39 | 39 | 1500 | 1500 | 1500 | | 56000 | 56000 | 2.2 Meg | 2.2 Meg | 2.2 Meg |
| | | 43 | | | 1600 | | | 62000 | | | 2.4 Meg |
| 47 | 47 | 47 | | 1800 | 1800 | 68000 | 68000 | 68000 | | 2.7 Meg | 2.7 Meg |
| | | 51 | | | 2000 | | | 75000 | | | 3.0 Meg |
| | 56 | 56 | 2200 | 2200 | 2200 | | 82000 | 82000 | 3.3 Meg | 3.3 Meg | 3.3 Meg |
| | | 62 | | | 2400 | | | 91000 | | | 3.6 Meg |
| 68 | 68 | 68 | | 2700 | 2700 | 100000 | 100000 | 100000 | | 3.9 Meg | 3.9 Meg |
| | | 75 | | | 3000 | | | 110000 | | | 4.3 Meg |
| | 82 | 82 | 3300 | 3300 | 3300 | | 120000 | 120000 | 4.7 Meg | 4.7 Meg | 4.7 Meg |
| | | 91 | | | 3600 | | | 130000 | | | 5.1 Meg |
| 100 | 100 | 100 | | 3900 | 3900 | 150000 | 150000 | 150000 | | 5.6 Meg | 5.6 Meg |
| | | 110 | | | 4300 | | | 160000 | | | 6.2 Meg |
| | 120 | 120 | 4700 | 4700 | 4700 | | 180000 | 180000 | 6.8 Meg | 6.8 Meg | 6.8 Meg |
| | | 130 | | | 5100 | | | 200000 | | | 7.5 Meg |
| 150 | 150 | 150 | | 5600 | 5600 | 220000 | 220000 | 220000 | | 8.2 Meg | 8.2 Meg |
| | | 160 | | | 6200 | | | 240000 | | | 9.1 Meg |
| | 180 | 180 | 6800 | 6800 | 6800 | | 270000 | 270000 | 10.0 Meg | 10.0 Meg | 10.0 Meg |
| | | 200 | | | 7500 | | | 300000 | | | 11.0 Meg |
| 220 | 220 | 220 | | 8200 | 8200 | 330000 | 330000 | 330000 | | 12.0 Meg | 12.0 Meg |
| | | 240 | | | 9100 | | | 360000 | | | 13.0 Meg |
| | 270 | 270 | 10000 | 10000 | 10000 | | 390000 | 390000 | 15.0 Meg | 15.0 Meg | 15.0 Meg |
| | | 300 | | | 11000 | | | 430000 | | | 16.0 Meg |
| 330 | 330 | 330 | | 12000 | 12000 | 470000 | 470000 | 470000 | | 18.0 Meg | 18.0 Meg |
| | | 360 | | | 13000 | | | 510000 | | | 20.0 Meg |
| | | | | | | | | | 22.0 Meg | 22.0 Meg | 22.0 Meg |

AVAILABLE THROUGH PARTS DISTRIBUTORS: For the name of the nearest distributor stocking Stackpole resistors, switches and "EE" iron cores, write Distributors Division, Stackpole Carbon Company, 26 Rittenhouse Place, Ardmore, Pa.



COILS

from 6' giants to *half-inch* midgets

**When you need coils . . . whether it be just a few for research and development or huge quantities for volume production . . . you'll find your needs right up B&W's alley. Regardless of size or type . . . from 6' x 48" variometer type loading coils down to half-inch miniductors, both shown above.**

**And you'll value the top coil performance you get, based on two decades of specialized manufacture. B&W's twenty years of experience stems from the commercial manufacture of the world's first air-inductor through *single layer solenoid coils . . . universal units with single, multiple pie, or progressive windings . . . r-f, i-f, and oscillator coils . . . traps, discriminators, toroids, filters, r-f and delay line chokes.***

**Wherever your coil requirements lie, you'll find Barker & Williamson ready, willing, and able to solve them. Write now for complete information on B&W coil development and manufacturing facilities.**

B&W **Barker & Williamson, Inc.**
237 Fairfield Ave., Upper Darby, Pa.

## IRE People

The election of **F. G. Marble** (A'38–SM'44) as Vice-President in charge of sales of the Boonton Radio Corporation has been announced. Mr. Marble has been sales manager of Boonton Radio Corporation since 1951. Prior associations were with Bell Telephone Laboratories as a member of the technical staff and with Kay Electric as Sales Manager.

A native of Mississippi, Mr. Marble was graduated from Mississippi State College where he received the B.S. degree in E.E. and from Massachusetts Institute of Technology where he received the M.S. degree in E.E.

❖

C. E. Beard

**C. E. Beard** (S'50–A'51) has been appointed sales manager for U. S. Air Force equipment manufactured by General Electric's Heavy Military Electronic Equipment department. He was formerly a project manager for Air Force ground radar equipment. A native of Asheville, N. C., he has been with G. E. since 1950 when he was a field service representative for the Commercial Equipment Department.

Mr. Beard served with the Air Force, 1942–46, as a radar development officer at the Air Proving Ground Command, Eglin Field, Fla., and as theater electronics countermeasure officer for the China-Burma-India theater. Following the war he joined the engineering staff of Radiohio, Inc., at Columbus, Ohio.

He is a graduate of Ohio State University with a B.S. degree in electrical engineering, a member American Institute of Electrical Engineers, and a charter member of the IRE Professional group on Electronics and Navigation.

❖

K. C. Black

The appointment of **K. C. Black** (M'29–SM'43–F'49) as head of Raytheon Manufacturing Company's communications engineering department, has been announced. His new position makes him responsible for the design and development of communications products to fill out Raytheon's expanding line of electronic equipment.

Formerly, Dr. Black was business manager of the Polytechnic Research and Development Company of Brooklyn, N. Y. He obtained the bachelor's, mas-

*(Continued on page 74A)*

COLLINS
MOD. PL.
P.A. PL.
P.A. GRID

**COLLINS**

# COVERS the WORLD!

## 618S TRANCEIVER

for WORLD-WIDE Airborne Communications

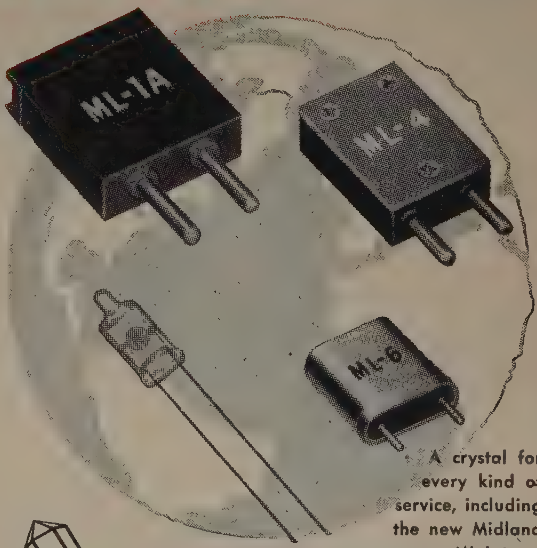
## ...and of course it uses *Midland* CRYSTALS

100-WATT POWER ON 144 CHANNELS gives the Collins 618S Tranceiver truly world-wide operation. Collins airborne HF communications equipment is *first choice of most U. S. trans-oceanic airlines,* and of many foreign and domestic carriers, as well as private and military aviation.

*Midland crystals* do the key job of frequency control in the 618S Tranceiver as in all Collins aviation equipment. In this critical service, there can't be any question of stability, precision, and sure-fire performance under toughest conditions.

*Midland Crystals* measure up to Collins' strict standards because every one of the millions of these crystals in use today is a product of Midland Quality Control. This is the system that constantly checks every crystal at every step in processing.

*Midland employs* the finest technical skill and production facilities in the industry to make sure you'll get completely dependable crystal quality and performance.



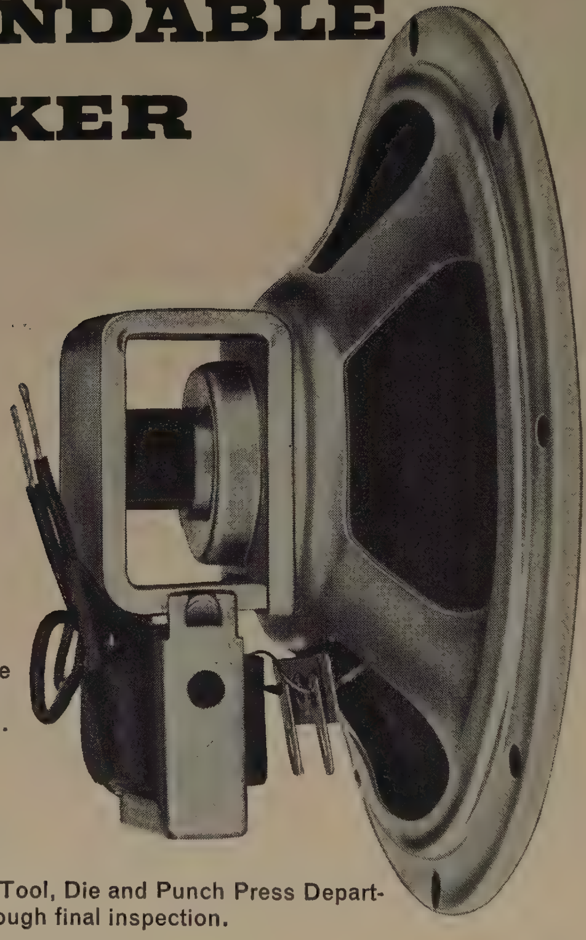
A crystal for every kind of service, including the new Midland Miniatures

*Whatever your Crystal need, conventional or specialized*
*When it has to be exactly right, contact*

***Midland***

**MANUFACTURING COMPANY, INC.**
3155 Fiberglas Road • Kansas City, Kansas

WORLD'S LARGEST PRODUCERS OF QUARTZ CRYSTALS



LOWER YOUR SET COSTS WITH THIS LOWER-PRICED DEPENDABLE SPEAKER

A line of 4″ and 5″ speakers designed for peak performance. Break off or cast magnet may be used.

Low priced only because of unusually efficient manufacturing techniques.

Produced under rigid quality control. Metal stampings completely manufactured in our own Tool, Die and Punch Press Departments. Exceptionally thorough final inspection.

Plugs, transformers and/or brackets to your specifications.

Lower your set costs with this dependable speaker. Write for further information TODAY.

OTHER HEPPNER PRODUCTS:
Ion Traps, Centering Devices, Fly-Back Transformers and Focomags.

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MANUFACTURING COMPANY
ROUND LAKE, ILLINOIS
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Specialists in Electro-Magnetic Devices

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## I R E People

*(Continued from page 72A)*

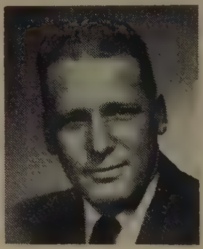
ter's, and doctor's degrees in physics from Harvard University, and, from 1927 to 1929, was an instructor there in physics and electrical engineering. He has done engineering and research work for the American Telephone & Telegraph Company, Radio Frequency Laboratory of Boonton, N. J.; Boonton Research Corp., Bell Telephone Laboratories, Aircraft Radio Corp. of Boonton, and Air Associates, of Teterboro, N. J.

During World War II, Dr. Blacks' worked in the fields of proximity fuses, radar, and electronic counter measures. From 1949 to 1952 he was chief scientist at the Naval Air Development Center, Johnsville, Pa., where he was concerned with programs in communications, sonar, radar, counter measures, armament development, and missile guidance.

He is chairman of the Professional Group on Aeronautical and Navigational Electronics.

❖

**Nathaniel B. Nichols** (SM'53), manager of Raytheon Manufacturing Company's research division, has been appointed an assistant vice-president.



N. B. Nichols

Mr. Nichols received degrees in physics at the Central Michigan College and the University of Michigan. During World War II, he was associated with the radiation laboratory of M. I. T., where he headed the servo group of the fire control division. Subsequently, he became research director of the Taylor Instrument Companies, leaving in 1950 to accept a professorship at the University of Minnesota. An authority in servo-mechanisms and electronics automation, he joined the Waltham, Mass., electronics firm in 1951. He did work that eventually led to the mass production of transistors, the tiny, durable substitutes for vacuum tubes; helped develop the "Micronaire" room air cleaner, a home appliance which removes dust, pollen, and other allergy irritants from the air; the "Ultrasonic Machine Tool" which uses sound waves to drive a cutting tool or drill through glass, stone, tungsten carbide, or precious gems; and the Raytheon single-motion duplicator, an electronic brain for machine tools, which guides them to reproduce hundreds of exact replicas of one master part.

Mr. Nichols is a member of the Instrument Society of America, the American Physical Society, the American Chemical Society, the American Association for the Advancement of Science, American Society of Mechanical Engineers, and the American Institute of Electrical Engineers.

*(Continued on page 76A)*

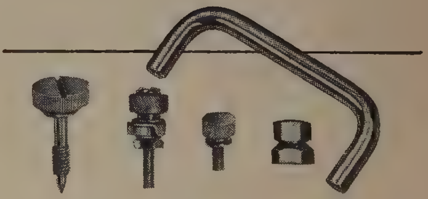
# No cracks, please

You'll find no radial cracks in C.T.C. terminal boards, or "cracked" rivet shanks on terminals. And there's a good reason for this.

Our swaging machines use tools that we designed ourselves in order to prevent just such damage. Terminals are fastened securely — *and carefully*. You benefit from a board that has no "weak spots" — that can give you the service you have a right to expect. And, of course, you also benefit from all the other quality control details that enable us to offer our customers *guaranteed* components — custom or standard. Coatings are smoothly applied — no wrinkles, no heavy deposits. C.T.C. terminals are made from certified stock that is free from defects. And the terminals themselves are guaranteed, even to the thickness of the coatings.

This C.T.C. quality control is given to all C.T.C. products including insulated terminals, coil forms, coils, swagers, terminals and capacitors. For all specifications and prices, write to Cambridge Thermionic Corporation, 456 Concord Avenue, Cambridge 38, Mass. West Coast manufacturers contact: E. V. Roberts, 5068 West Washington Blvd., Los Angeles 16 and 988 Market St., San Francisco, California.

*Terminal Board Data.* C.T.C. makes both standard boards and to your own specifications. Standard boards in cotton fabric phenolic, nylon phenolic or grade L-5 silicone impregnated ceramic. Custom made in cloth, paper phenolic, melamine, epoxy or silicone fibreglas laminates, imprinted as required and lacquered or varnished to specifications MIL-V-173 and JAN-T-152.

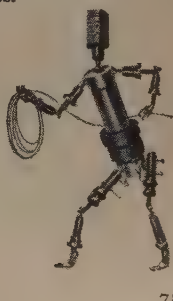


*A wide variety of hardware* is available at C.T.C. — all of it quality controlled and guaranteed for durability. This hardware includes terminal board brackets, standoff mounts, spacers, tube clamps, panel screws, thumb screws, dial locks, shaft locks, handles and handle ferrules.

**CTC**

**CAMBRIDGE THERMIONIC CORPORATION**

*makers of guaranteed electronic components, custom or standard*



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Precision Attenuation to 3000 mc!

TURRET ATTENUATOR featuring "PULL-TURN-PUSH" action

SINGLE "IN-THE-LINE"
ATTENUATOR PADS
and
50 ohm COAXIAL
TERMINATION

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COAXIAL LINE TERMINATION 50 OHMS

FREQUENCY RANGE:
dc to 3000 mc.
CHARACTERISTIC IMPEDANCE:
50 ohms
CONNECTORS:
Type "N" Coaxial female fittings each end
AVAILABLE ATTENUATION:
Any value from .1 db to 60 db
VSWR:
<1.2, dc to 3000 mc., for all values from 10 to 60 db
<1.5, dc to 3000 mc., for values from .1 to 9 db
ACCURACY:
±0.5 db
POWER RATING:
One watt sine wave power dissipation

*Send for free bulletin entitled "Measurement of RF Attenuation"*

•

*Inquiries invited concerning pads or turrets with different connector styles*

STODDART AIRCRAFT RADIO Co., Inc.
6644-C Santa Monica Blvd., Hollywood 38, California · Hollywood 4-9294

## I R E People

(Continued from page 74A)

**H. H. Goode** (SM'52) has been appointed a professor of electrical engineering at the University of Michigan. He has assumed the new position in addition to his duties as director of the Willow Run Research Center and assistant director of the Engineering Research Institute.

H. H. GOODE

Mr. Goode received the B.S. degree at New York University, the B.Ch.E. degree at Cooper Union, and the M.A. degree at Columbia. He served as assistant to the Deputy Commissioner of the New York City Health Department from 1935 to 1938, as assistant director for statistics on the Commission for Study of Crippled Children, New York City, from 1938 to 1940, and as statistician-in-charge of the Central Statistical Division at the New York Department of Health from 1940 to 1942.

During the war, Mr. Goode was a research associate at Tufts College. He later joined the staff of the Office of Naval Research at the Special Devices Center where he did work in computer research, simulation training, aircraft instrumentation and control design antisubmarine warfare, and weapon system design.

He is a member of the American Association for the Advancement of Science, the Institute of Mathematical Statisticians, the American Mathematical Society, the Association for Computing Machinery, and Mu Alpha Omicron.

⁂

**R. L. Palmer** (SM'51) has been appointed director of engineering at International Business Machines Corporation. Before his appointment, he had been manager of the company's engineering laboratory at Poughkeepsie, N. Y.

Mr. Palmer is a graduate of Union College with the B.S. degree in electrical engineering.

⁂

**H. E. Ellithorn** has been named head of the department of electrical engineering at Notre Dame.

A specialist in network theory, Prof. Ellithorn did his undergraduate work at Union College and received a master's degree at Harvard. He joined the Notre Dame faculty in 1940 and received the Ph.D. in physics from the university in 1945. From 1935 to 1938, he was director of the engineering laboratory at the Sylvania Electric Company, Salem, Mass.

Dr. Ellithorn is a member of the American Institute of Electrical Engineers, the American Association of Engineering Educators, the American Institute of Physics, and Sigma Xi.

(Continued on page 78A)

# ELECTRO TEC SLIP RING ASSEMBLIES

*PATENTS PENDING

## HIGH TEMP PLASTIC!

*NEW ETC-7 (POLYESTER RESIN) USED ON ILLUSTRATED PART FOR HIGH TEMPERATURE OPERATION*

# —for high temp applications!

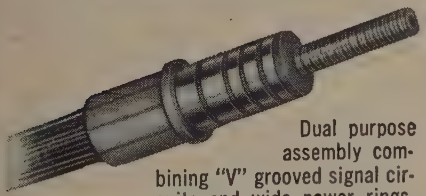
## HARD GOLD RINGS!

*24 KT. SOLID GOLD RINGS — ENTIRE RING THICKNESS ELECTRODEPOSITED* UNIFORM HARDNESS, 90 to 100 BRINNELL.*

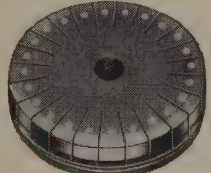
COURTESY LEAR, INC.
— these two features were incorporated in the assembly illustrated above, having 45 rings, dia. .180", ring width .020", barrier width .010". Overall length, less leads 1.763".

Electro Tec Corp., in its constant endeavor to keep pace with the most exacting requirements, has developed these new processes and products. They provide flawless performance under conditions far exceeding the capabilities of other types of construction. Where high temperature is involved, the superiority of these assemblies is so marked, that acceptance has been industry-wide. At the same time, an increasing number of users are specifying these assemblies for the ultimate in dependability under normal operating conditions. Inquiries will receive prompt attention; no obligation.

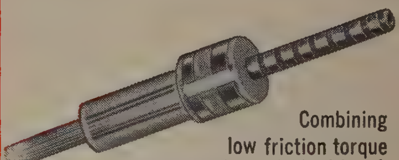
← 72 rings on integral support — no accumulated tolerances — fulfills electrical, minimum weight and space requirements.



Dual purpose assembly combining "V" grooved signal circuits and wide power rings.



Miniature high speed sampling switch — 24 channels.



Combining low friction torque slip rings (.060 dia.) with reference switch segments.

**NEW ETC-7 (POLYESTER RESIN) WITHSTANDS TEMPERATURE RANGE FROM —60° to +500°F.**

*PRODUCTS OF PRECISION CRAFTSMANSHIP*
*BY A NEW AND REVOLUTIONARY PROCESS*

**ELECTRO TEC CORP.**
SOUTH HACKENSACK, NEW JERSEY

Simul-Scopic* Signals

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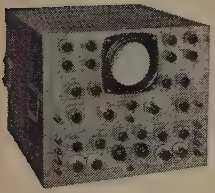
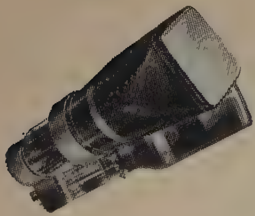
OUT OF SCOPES

It's all done by combining any number of electron guns up to ten in a single cathode ray tube. Then, when you have to measure simultaneous phenomena, you've actually got a number of oscilloscopes in one—all operating continuously without the disadvantages of electronic-switching or an optical system. And only ETC multi-channel scopes and multi-gun tubes make Simul-Scopic signals available to meet such a wide variety of individual needs.



MULTI-CHANNEL SCOPES

. . . with the combination you need of band width, gain, sensitivity, frequency response, with or without film strip recording. Separate intensity, focus, and axes controls for each channel.



MULTI-GUN TUBES

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## I R E People

*(Continued from page 76A)*

**W. W. Garstang** (A'31–M'35–SM'41) has been appointed chief engineer of the radio division of Allen-Bradley Company, manufacturers of radio, television, and electronic components, in Milwaukee, Wisconsin.

Prior to joining Allen-Bradley Company, Mr. Garstang was vice-president in charge of manufacturing at the Chicago plants of Raytheon Manufacturing Company. Previous to that he was president of Electronic Laboratories Inc. of Indianapolis. Several patents have been issued to him covering the design and manufacture of vibrator-type rectifiers for radio apparatus.

Mr. Garstang is a graduate of the University of Wisconsin, where he majored in physics.

## Membership

**The following transfers and admissions were approved and are effective as of November 1, 1954:**

### Transfer to Senior Member

Alinsky, J. W., 93 N. Dearborn Ave., Indianapolis, Ind.
Alter, A. C., c/o Aramco, Adelheidstraat 300, The Hague, Netherlands
Althouse, J. M., 227 Shady La., Dayton 3, Ohio
Angelo, E. J., Jr., Polytechnic Institute of Brooklyn, Brooklyn, N. Y.
Bambara, J. E., 671 Argyle Rd., Brooklyn 30, N. Y.
Barber, A. W., 32–44 Francis Lewis Blvd., Flushing 58, L. I., N. Y.
Bugg, K. W., Board of Education, 14 Fl., City Hall, Atlanta, Ga.
DeLano, R. H., 7890 Flight Pl., Los Angeles 45, Calif.
Freeman, H., 90-26—171 St., Jamaica 32, L. I., N. Y.
Gage, D. D., Dunellen Dr., Towson 4, Md.
Hawkins, J. E., Box 1590, Tulsa 1, Okla.
Hull, D. E., 2816 Villa St., Los Alamos, N. Mex.
Jensen, K. K., 3751 Sunswept Dr., N. Hollywood, Calif.
Kirby, R. C., National Bureau of Standards, Sec. 82.2, Washington, D. C.
Lee, C., 807 Draper Rd., Blacksburg, Va.
Miller, R. H., Jr., 10606 Snyder Rd., LaMesa, Calif.
Mukerji, M. M., Electrical Engineering Dept., College of Engineering and Technology, Calcutta 32, India
Schatz, F. W., 44 Lyndon Rd., Whitesboro, N. Y.
Spaulding, C. P., 1530 Mirasol, San Marino, Calif.
Swan, M. L., 3769 E. Green St., Pasadena 10, Calif.
Wessels, P. S., Convair, Pomona Div., Group 233, Box 1011, Pomona, Calif.
Wyland, G. P., 17183 Rayen St., Northridge, Calif.

### Admission to Senior Member

Bijl, P. C. J., c/o Compania Shell de Venezuela, Apartado 19, Maracaibo, Venezuela.
Brown, H. R., Jr., 650 S. College Ave., Whittier, Calif.

*(Continued on page 82A)*

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*Published Monthly by*

The Institute of Radio Engineers, Inc.

VOLUME 42 — *December, 1954* — NUMBER 12

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# An Expanding I.R.E.

## Chairmen of Recently Formed Sections and Professional Groups

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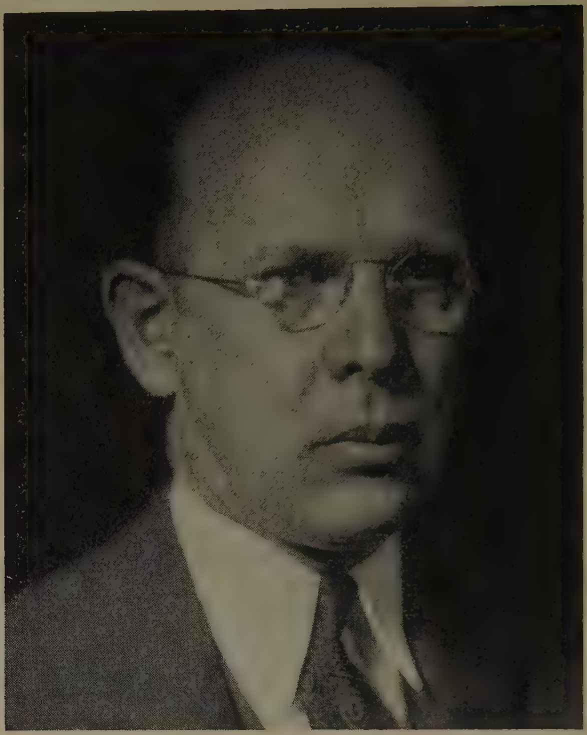
Professional Group on Production Techniques



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# The Shoemaker's Child—No Longer Unshod?

WILSON H. HANNAHS, ASSOCIATE, IRE
Automatic Production Research Co., Pleasantville, N.Y.

The engineering world is widely aware that the designing of electronic equipment has markedly changed in the last eight years. For convenience, this changed way of thinking is often referred to as "packaging" or "miniaturizing" equipment. Hidden beneath these casual generalizations is a whole groop of vital new principles in design, generated by the needs of providing equipment of increasing complexity which will yet be dependable in harsh military environments, serviceable in industrial plants, and low in cost for competitive trade.

Competition for the home market and impending shortages of military gear have motivated a second and more significant engineering trend toward the design of equipment for mechanized manufacture, and in 1954 we are witnessing perhaps a climacteric in the reorganization of all manufacturing of complex devices, because the eyes of industry are focused on electronics.

Automatic production of simple products—raw materials, foodstuffs, and chemicals—has long been accepted, and the machinery for component manufacture has gradually been evolved to increasingly difficult function with little conscious acknowledgment. But the mechanization of radio manufacture represents a breakthrough in technical advance, having pronounced significance.

Patent literature reveals that inventors were thinking toward the objective of "easier assembly and disassembly of electrical equipment" even before this century, and that some forms of printed circuit were proposed for the manufacture of radio's fundamental circuit elements when galena detectors were still more common than the audion. This and many other proposals for improving manufacture were long deferred from application until the introduction of proximity fuzed ammunition, with its fantastic requirements for size, ruggedness, reliability, and producibility, brought the Bureau of Standards to a review of the limitations and possibilities inherent in the traditional embodiment of electronic circuits. The NBS investigation touched off other research programs, none of which provided a panacea for manufacturers, but each adding some valid technique.

The complexity coming with computers, and the spread of electronics in navigation and fire control, also raised problems of maintenance and operation of such magnitude as to call forth new concepts in the engineering for endurance, fault location, repair, and accurate human perception. Both the design and the designer were changed by the need for tropicalizing and both were further changed when missile equipment brought requirements for extensive thermal consideration.

Today's equipment design proceeds out of the coordination of large groups of specialists whose training represents heavy overhead, a task particularly wasteful and lengthy because little of the new engineering is found in texts or in any authoritative sources.

This year, which opened with the New York Section of the IRE sponsoring a Symposium on the Automatic Factory, which has seen the presentation of several symposia and expositions on automation, and which is seeing the introduction of mechanized assembly by more than one radio-TV producer, witnesses yet another marker in the formation of an IRE Professional Group on Production Techniques, which took place September 28.

This vitally interested group, by sponsoring further symposia and guiding the publication of needed technical information, will do much to strengthen and consolidate the newer art of design and manufacture into sound engineering practice.

In electing as first president of the Administrative Committee, Ralph R. Batcher, whose biography appears in this issue, the new group enjoins him—"to promote technical progress in the design and manufacture of electronic equipment through manual or automatic means, by collecting and distributing information on new advances in methods, processes, materials and components. This includes the application of new materials and components and the details of how to improve operating simplicity, reliability, serviceability, cost and appearance of equipment of all kinds including miniaturization, encapsulation, circuit packaging and new assembly techniques."

Expansion into this important area, through formation of local chapters of the group, can also be foreseen as growth in the stature and service of the IRE to its membership and the world's industry.

# Review Papers for the Proceedings of the I.R.E.

The annual review of radio progress, which formerly appeared in the PROCEEDINGS once a year, has been discontinued. In its stead the IRE plans to publish a series of review papers, covering progress in various fields. The paper beginning on the following page is the first in this series.

Men of recognized standing in their fields will be invited to write these papers. Papers covering a given field will be published at irregular intervals of perhaps, 1, 2 or more years. When sufficient progress in a field beyond that covered in the last paper has been made, a new paper will be solicited.

What should such a paper be like?

An intelligent engineer in some other field should be able to read a review paper, preferably with enjoyment, and at least without pain. It should tell him what important progress has been made since the last paper appeared. It should tell him what the current difficulties and unsolved problems are, and what is being done about them.

A review paper should not be tutorial in the sense of teaching readers mathematical techniques or proving an author's assertions to his readers. Equations, if used, should be few and simple. The paper should state, in plain, simple English, the author's expert opinion. An author may want to get the opinions of others in the field, perhaps by letting them read his manuscript. However, the paper must present the author's own views; it should not be an unintegrated compilation of other's views.

A reader may want to study in detail some matters mentioned in the paper. The paper should have an adequate bibliography of recent work.

Because the average reader will be unfamiliar with the field covered, the author should not merely describe recent work, but he should in some way clearly evaluate it, either by showing how it is an advance over earlier work, or by showing why it is important.

Review papers will be of varying lengths. A paper must be long enough to cover important progress in the field since the last paper and to explain clearly points covered. It should not say much on minor matters, but should refer readers to other sources of information concerning them. The author may have to limit his field in order to write a paper of reasonable length; thus, at the outset, he should state the intent and scope of his paper. The initial review paper in a field may have to be longer than subsequent papers.

While review papers will differ, because authors and fields differ to some degree, a pattern should evolve through editorial comment prior to publication and through readers' comment after publication. Therefore, remarks on review papers are earnestly solicited.

—*The Editor*

# Some Recent Advances in Microwave Tubes*

J. R. PIERCE†, FELLOW, IRE

*Summary*—**This is a review paper which discusses in simple terms high-power klystrons, double-tuned circuits for reflex klystrons, noise in traveling-wave tubes and its reduction by velocity-jump or space-charge-wave deamplification, periodic magnetic focusing of electron beams, and the backward-wave oscillator.**

IT WOULD BE almost impossible to write a paper presenting all recent advances of all sorts in the field of microwave tubes. For one thing, there is a great deal of classified work on microwave tubes. Particularly, much of the work on tubes for radar, such as pulsed magnetrons, is classified, and we may expect that things which are important and new in this field will be classified. There is other classified tube work as well.

Even aside from the problem of classification, however, there is the problem of the many sorts and the great extent of microwave tube work. In this paper, then, certain particular advances which the writer believes may be of interest or of use to engineers outside of the tube field have been selected to represent progress in the field, and these will be described briefly. Nothing at all will be said about magnetrons, partly because of the problem of classification, and partly because of the writer's unfamiliarity with the subject and his belief that he could not treat it fairly. Experts in various other fields may also feel that something they would like to have seen here has been slighted, and for this the writer can only apologize.

Advances are of many different sorts, so that it is not only among the most recent types of tubes that we should look for advances. Klystrons may now seem very old to some of us, for the Varians described them in 1939, that is, fifteen years ago. Recently, however, there has been a particular sort of advance in the field of klystrons: Tubes with very high powers have been made and put to practical use.

Fig. 1 shows the essential parts of a klystron. At the left is the cathode, from which a long electron beam is accelerated, finally to be collected at the collector to the right. The beam first passes through the input resonator. The input signal produces a longitudinal electric field across the part of the resonator through which the beam passes. This field alternately retards and accelerates the electrons passing through the resonator. The retarded and the accelerated electrons all travel along through a drift space. There, the accelerated electrons catch up with the retarded electrons which left the input resonator earlier, so that bunches are formed. These bunches are composed of electrons which passed through the input resonator while the field was changing from retarding to accelerating. These bunches pass through the output resonator and induce a current from which the output is derived.

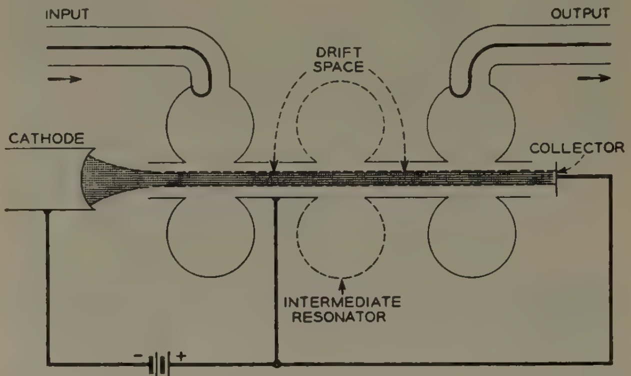


Fig. 1—This schematic diagram shows the important parts of the klystron amplifier. An electron beam originates at a cathode and is finally collected at a collector. Commonly, it is focused by a longitudinal magnetic field. The longitudinal radio-frequency electric field across the input resonator alternately slows down and speeds up the electrons which pass through it. In the drift space, the fast electrons catch up with the slow electrons which left earlier, and so the electron beam is bunched. The bunches induce a signal in the output resonator when they pass through it. By use of an intermediate resonator, in effect a two-stage amplifier is obtained in one tube.

Sometimes an intermediate resonator is placed between the input and output to give, in effect, a two-stage amplifier in one tube. The bunched electron beam produces a field across the intermediate resonator, and this again retards and accelerates the beam, that is, velocity modulates it, anew. In tubes for very broad-band operation, several intermediate resonators may be used.

The four-foot tubes of Fig. 2, on the following page, show that klystrons have become big business, at least as far as power and size go. The tube illustrated is the Stanford pulsed klystron.[1–2] This 10.5 cm amplifier ordinarily operates at 300 kilovolts with a beam current of 190 amperes, giving an input of 57 megawatts. At 30 per cent efficiency the output is 17 megawatts. A modified version of this tube has been operated at 370 kv and 190 amperes at 43 per cent efficiency, giving a 30 megawatt pulsed output.

In the left in Fig. 2 the tube is shown without focusing coils. The cathode is located at the bottom. Sticking out to the left we see a pumping connection. The input and output waveguides extend to the right from the input and output resonators, and the intermediate resonator may be seen between these. To the right the tube is

---

* Original manuscript received by the IRE, September 30, 1954.

† Bell Telephone Laboratories, Inc., Murray Hill, N. J.

[1] M. Chodorow, E. L. Ginzton, and E. J. Nalos, "The debunching of electron beams," PROC. I.R.E., vol. 41, pp. 999–1003; August, 1953.

[2] M. Chodorow, E. L. Ginzton, I. R. Nielson, and S. Sonkin, "Design and performance of a high-power pulsed klystron," PROC. I.R.E., vol. 41, pp. 1584–1602; November, 1953.

shown with two magnetic focusing coils. Twenty-one such tubes will be used in connection with the Stanford linear accelerator to give electrons a design energy of one billion electron volts; with a partial complement of tubes an energy of 595 mev has been reported.

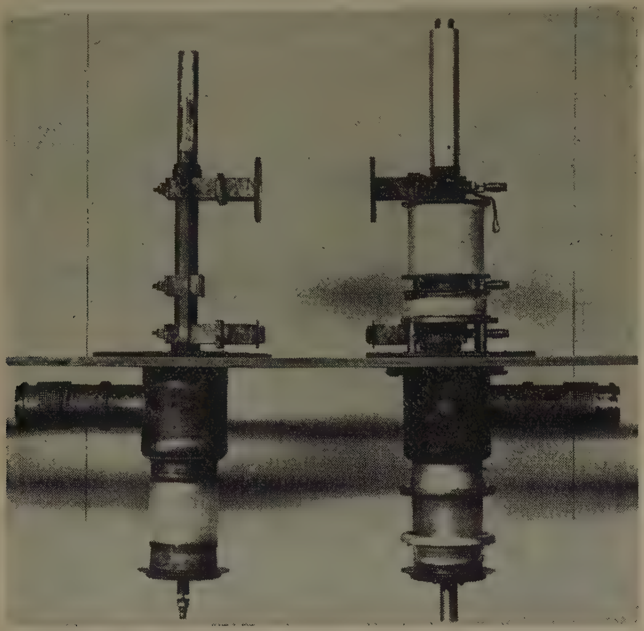


Fig. 2—The Stanford high-power pulsed klystron. It is shown at the left without focusing coils, and at right with focusing coils and with the water jacket around the final anode or collector. The lower end houses the gun. The large pipe is for pumping. Above, we see the input resonator and waveguide, the intermediate resonator, the output resonator and waveguide, and the collector. The tube produces as much as 30 megawatts pulsed power at a wavelength of 10 centimeters.

The right-hand tube of Fig. 3 is a Varian klystron for use in television transmitters. Six models of this tube are made, covering the range from 470–890 megacycles. The tube is linear to an output of 12 kilowatts. It operates at 2½ to 3 amperes and 17½ kilovolts and gives a gain of 27 db. The required drive is 60 watts.

Television klystrons somewhat similar to these tubes, but using ceramic seals and external resonators, are made by Eitel McCullough.[3] Sperry has made a 4 megawatt pulsed klystron. Other high-power klystrons have been made for a variety of purposes.

I have quoted these results on klystrons largely to show that through advances in the art, microwave tubes do finally reach a state in which they are used to do big and important jobs. Certainly, the final development of a useful tube represents an important advance in the art. However, most of the other things that I will describe are advances which are still in a much earlier state, and many of these may not be applied practically for a number of years.

Let us now consider how some of these other advances in microwave tubes have been made. One way in which one can make an advance is to take a tube which already exists and, through an advance in circuitry, achieve a new result with it. The reflex klystron is an "old" type of tube.[3] Much good work has been done in understanding its functioning and in improving its operation. However, by adding a double-tuned circuit to a commerical reflex klystron, E. D. Reed was able to make an important and useful advance.[4]

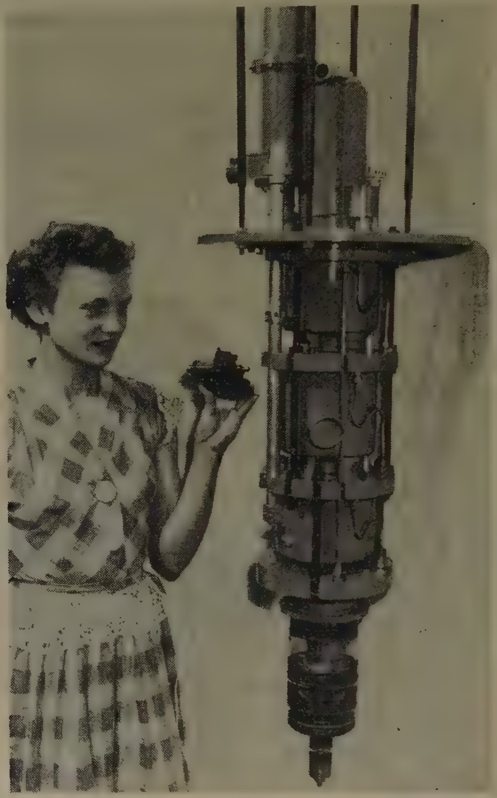


Fig. 3—Varian television klystron compared with a low-power microwave klystron. The large tube is linear to a 12 kw output.

Fig. 4 shows a reflex klystron. An electron beam from the cathode crosses a resonator in which there is an alternating electric field. This alternately accelerates and retards the electrons. The velocity-modulated electron beam enters a region of retarding field, produced by a negative repeller. Just as in the case of throwing objects up against the retarding field of gravity, the faster the initial velocity, the longer the object (an electron in this case) takes to return. Thus, in the retarding field produced by the repeller, the slowed-down electrons catch up with the speeded-up electrons which left earlier, so that the electrons which pass through the resonator while the field is changing from accelerating to retarding are bunched together as they return. The bunched electron beam sustains oscillation in the resonator, and provides the power output.

When the repeller voltage is changed, the phase of the bunched current which returns through the resonator is changed, and the oscillator is tuned electronically. Fig. 5 shows some electronic tuning characteristics in which output power is plotted vs repeller voltage. That at the

[3] J. R. Pierce and W. G. Shepherd, "Reflex oscillators," *Bell Syst. Tech. Jour.*, vol. 25, pp. 460–690; July, 1947.

[4] E. D. Reed, "A coupled resonator reflex klystron," *Bell Syst Tech. Jour.*, vol. 32, pp. 715–766; May, 1953.

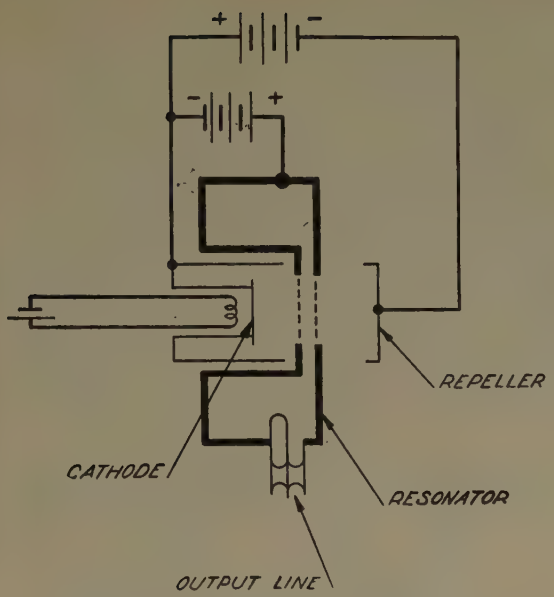
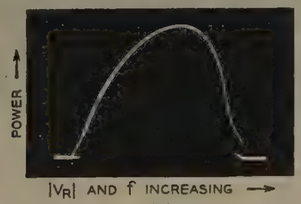
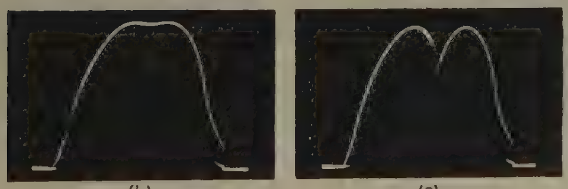


Fig. 4—The essential parts of a reflex klystron. The electrons from the cathode are velocity modulated in passing through the resonator. In the retarding field produced by the repeller, the slow electrons catch up with the fast electrons which left earlier. Changing the repeller voltage changes frequency of operation.

top is smooth and fairly typical. The characteristics at the bottom show hysteresis. As the repeller voltage is swept back and forth, the power vs voltage curve does not retrace itself, and, indeed, the frequency jumps so that certain central frequencies are never reached. This condition was accidentally introduced into certain wartime radar equipment, and it led to the unwarranted rejection of tubes for faults of the circuit.

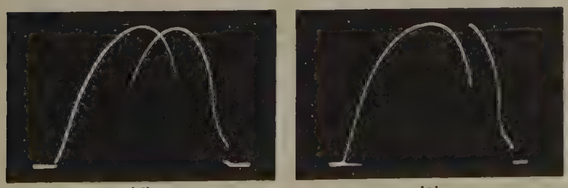


(a)
SECONDARY RESONATOR COMPLETELY DECOUPLED. HALF POWER ELECTRONIC TUNING RANGE EQUAL TO 49 MC.
(PEAK POWER = 100 MW)



(b)
SECONDARY RESONATOR COUPLING AND Q ADJUSTED FOR FLAT TOPPED MODE SHAPE. BANDWIDTH FOR POWER VARIATION OF ± 0.1 DB IS 59 MC.

(c)
MODE SHAPE FOR CONDITION OF CRITICAL COUPLING, i.e., $Q_SK = 1$



(d)
LOAD HYSTERESIS DUE TO OVER-COUPLING, i.e., $Q_SK > 1$

(e)
SAME AS (d) EXCEPT FOR UNIDIRECTIONAL (SAWTOOTH) REPELLER SWEEP

Fig. 5—Oscillographic traces showing output versus repeller voltage for a reflex klystron. The queer-shaped lower curves indicate multiple resonance of the circuit.

Reed knew that such queer repeller characteristics can be produced by doubly resonant circuits, and he decided to find out how to produce good repeller characteristics with such circuits as well. He used a Sylvania 6 BL 6 reflex klystron in a double-tuned circuit, as shown in Fig. 6. In this circuit the primary cavity surrounding the klystron is coupled, not only to the load, but to a secondary cavity of adjustable loss and frequency as well.

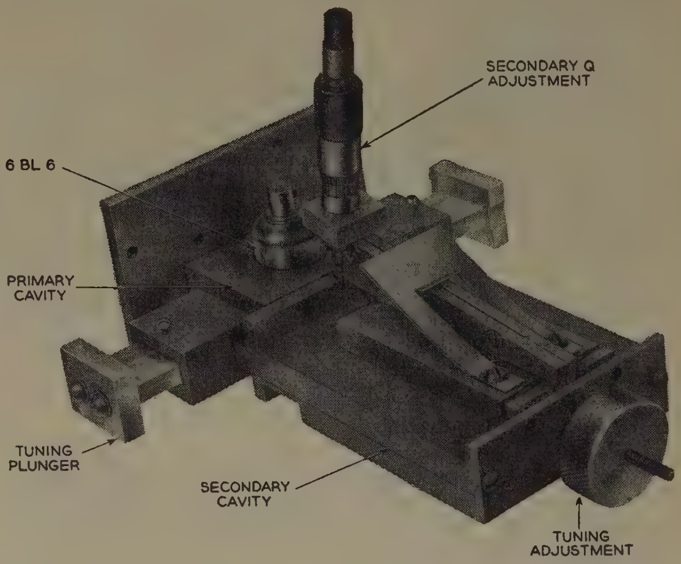


Fig. 6—A reflex klystron with a double-tuned circuit. The primary cavity is coupled, not only to the load, but to a secondary cavity of adjustable $Q$ as well.

In Fig. 7, on the following page, the admittance seen at the gap of the klystron is plotted, susceptance vs conductance, with frequency as a parameter. The straight vertical line to the left represents the behavior of a single-tuned circuit, for which, in the vicinity of resonance, the conductance remains constant and the susceptance increases uniformly with frequency. The looped curves to the right are for very strong coupling between the resonators. In this case, as the frequency is increased the susceptance at first increases with frequency and then, in traversing the loop, decreases with frequency, and then it increases again. At the frequencies corresponding to the right-most part of the loop, the tube cannot oscillate stably.

By combining theoretical knowledge concerning the electronic admittance of a reflex klystron as a function of amplitude of oscillation with circuit-admittance information, as illustrated in Fig. 7, Reed was able to calculate theoretical curves of amplitude and frequency versus repeller voltage. In Fig. 8, on the following page, the abscissa in curves $b$ and $c$ is normalized drift angle, which varies with repeller voltage but also changes with frequency. Curve $b$ shows power versus normalized drift

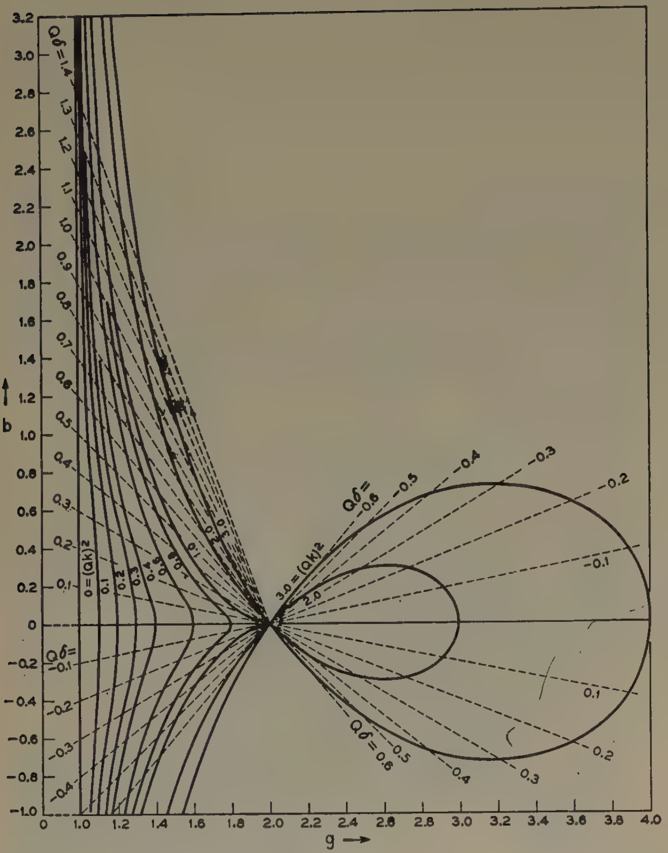


Fig. 7—Admittance plots for the admittance seen at the gap of a klystron with a double-tuned circuit. Susceptance is plotted versus conductance with frequency as a parameter. The vertical line to the left is for a single-tuned circuit (no coupling to the secondary resonator). The looped curves result in the discontinuous characteristics of Fig. 5.

angle for various values of a coupling parameter $QK$. We see that for $QK=1.6$, a flat-topped electronic tuning curve is obtained. Plot $c$ shows a quantity $Q\delta$, which is proportional to frequency deviation, versus normalized drift angle. We see that for small and large values of $QK$, the frequency versus drift angle, or repeller voltage, is very non-linear. However, for intermediate values of $QK$, a nearly linear variation can be obtained. Thus, a double-tuned circuit can be used not only to get a flatter amplitude curve, but a more linear frequency curve as well.

Fig. 9 shows a common type of oscillographic display used in measuring the $Q$ of a microwave resonator. This display shows reflected power versus frequency. In $b$, a reflex klystron with a double-tuned circuit was used as a variable-frequency source. It is apparent how much superior this is to the display of $c$, in which an ordinary single-tuned resonator was used.

Flattening the amplitude vs frequency characteristic and linearizing the frequency vs repeller voltage characteristic of a reflex klystron are important in other applications as well and notably in FM microwave transmitters.

While one way of making advances in microwave tubes is to improve the circuit of existing tubes, most important advances are made by improving the tubes themselves, and I propose to give some examples of such advances in the field of traveling-wave tubes.[5–6] Fig. 10

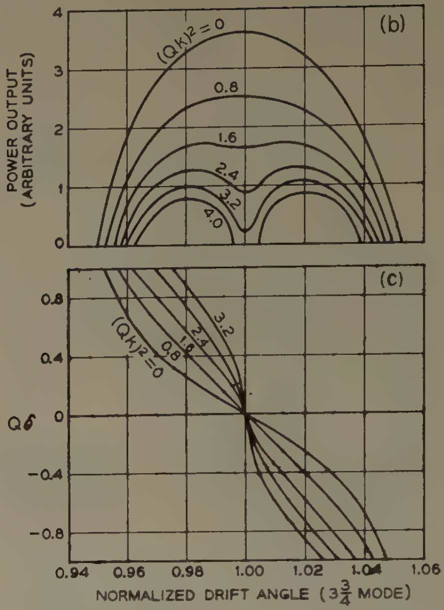
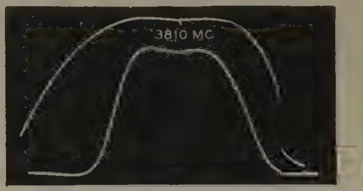


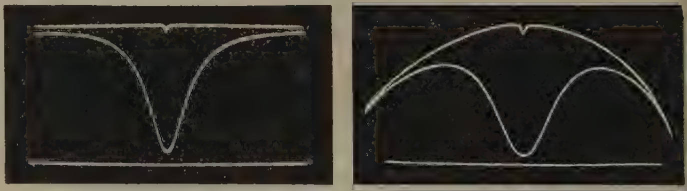
Fig. 8—Computed performance curves for a reflex klystron with a double-tuned circuit. In it, power output is plotted versus drift angle, which may be varied by changing resonator voltage. An increase in the parameter $QK$ means an increase in coupling. In $b$, a quantity $Q\delta$, proportional to the frequency deviation, is plotted versus normalized drift angle.



(a)

USE OF COUPLED-RESONATOR REFLEX KLYSTRON IN GAIN COMPARATOR TO DISPLAY BANDPASS CHARACTERISTIC OF MICROWAVE CHANNEL FILTER. TOP TRACE REPRESENTS INCIDENT POWER, LOWER TRACE TRANSMITTED POWER.

CENTER FREQUENCY OF FILTER = 3810 MC
PASS BAND = 28 MC



(b)

USE OF COUPLED-RESONATOR REFLEX KLYSTRON AS SWEPT FREQUENCY SOURCE IN DETERMINATION OF Q OF UNKNOWN RESONATOR BY REFLECTED POWER METHOD. TOP TRACE REPRESENTS POWER INCIDENT UPON CAVITY UNDER TEST, MIDDLE TRACE REFLECTED POWER AND LOWER TRACE ZERO POWER LEVEL. (NOTE FLATNESS OF INCIDENT POWER TRACE)

(c)

OSCILLOSCOPE DISPLAY FOR SAME RESONATOR RESULTING FROM USE OF CONVENTIONAL KLYSTRON AS SWEPT FREQUENCY SOURCE

Fig. 9—Oscillographic displays compare performance of a klystron with a double-tuned circuit with that of a klystron with a single-tuned circuit.

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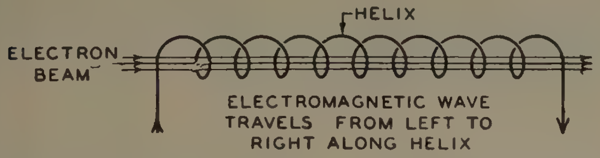
[5] J. R. Pierce, "Traveling-Wave Tubes," D. Van Nostrand Co., New York, N. Y.; 1950.

[6] R. Kompfner, "Reports on Progress in Physics," vol. 15, pp. 275–327; 1952.

s an old drawing showing the essential parts of a raveling-wave tube. These are a long narrow electron eam and a circuit capable of sustaining a slow electronagnetic wave, with a longitudinal component of elecric field, which can travel along in synchronism with he electrons of the beam. Commonly, the slow-wave ircuit is a helix, or a long coil of wire. In such a circuit, he wave travels along the wire with about the speed of ight. If the wire is 13 times as long as the axial length of he coil, the wave will travel along the beam with onehirteenth the speed of light, and the electrons will be in ynchronism with the wave if they are accelerated by bout 1,500 volts.



ig. 10—The essential components of a traveling-wave tube are an electron beam and a circuit carrying a slow electromagnetic wave with a longitudinal electric field. Such a circuit is often a helix, or a coil of wire. The wave travels along the wire with about the speed of light; thus, if in one foot of helix there is 13 feet of wire, the wave travels along the axis with about one-thirteenth the speed of light. If electrons are shot in at this same velocity, which can be obtained by accelerating them with 1500 volts, a cumulative interaction between the electrons and the wave takes place in the forward direction, so that a wave traveling along the helix is amplified. A wave traveling backward is little affected by the electron beam. In order to attain stability, loss must be put along the circuit, either uniformly or lumped toward the center. Such loss introduces an attenuation to the backward wave which is greater than the reduction in gain for the forward wave.

When the electrons travel along in synchronism with he wave, there is a cumulative interaction which results n amplification of the wave. At wavelengths of around 10 centimeters the power gain may be 1,000 to 10,000 imes, or even greater, in a distance of 10 inches. Because no resonant circuits are involved, the traveling-wave ube is inherently broad-band, and substantial gain has een obtained over bands of thousands of megacycles and of several octaves. Waves traveling backward, against the electron stream, are practically unaffected by its presence.

In order to make a stable and useful amplifier, attenuation must be added along the slow-wave circuit, either uniformly or, more often, lumped near the center. Such attenuation introduces a loss to the backward wave which is much greater than the amount by which it reduces the forward gain.

In Fig. 11, a few of the physical parts of the tube have been added—the heater, the cathode, the anode required to accelerate the electrons, and the collector to collect the spent electrons after they have served their purpose. A waveguide to guide the input signal to the helix and a short antenna or wire across the waveguide to put the signal onto the helix are shown; there is a similar output device. Fig. 12 shows a present-day traveling-wave tube. Such a tube is very little different in appearance from tubes which were made in 1946, but there is a difference in performance. Advances have been made.

Notably, there has been an improvement in noise figure. Typical early tubes had noise figures of around 30 db above thermal noise, but tubes have since been made with noise figures considerably lower than 10 db.

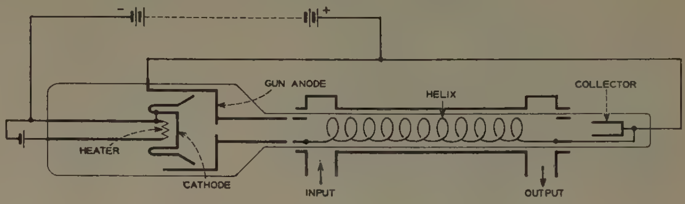


Fig. 11—A schematic representation of the parts of a complete traveling-wave tube, including the electron gun and waveguide input and output circuits.

In a radar or a microwave radio link, an improvement of 10 db in receiver noise figure increases to signal-to-noise ratio as much as an increase of 10 times in transmitter power. Early traveling-wave tubes had noise figures worse than that of a poor double-detection receiver using a silicon diode (crystal) mixer. The best present-day traveling-wave tubes have a better noise figure than the best double-detection receivers. This advance has come about, not through blind change and experimentation, but through a growing understanding of noise phenomena in traveling-wave tubes.

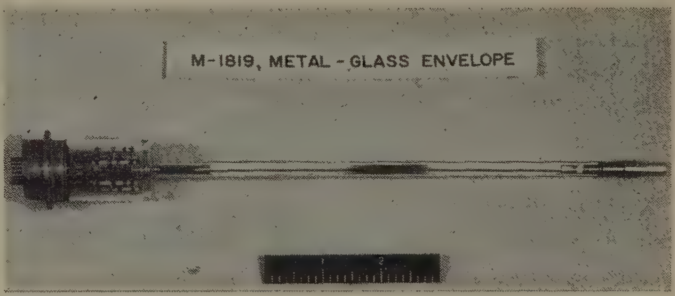


Fig. 12—A modern traveling-wave tube. This is a low noise tube for operation at 6,000 mc. It operates at 900 volts, 1 milliampere, and gives a gain of 20 db and a noise figure of around 8 db. The tube is used in a permanent magnet, with waveguide input and output circuits.

A vital step taken in this understanding was the work of Cutler and Quate.[7] A simplified theory seemed to show how to analyze and predict the noise in traveling-wave tubes.[5] This same simple theory predicted something rather startling, which some workers did not believe. It said that if an electron beam was accelerated from a cathode and allowed to flow through a long drift space, the noise current in the beam would vary periodically with distance; that is, there would be a standing wave pattern of noise along the beam. It seemed odd to some to think that a chaotic noise fluctuation should exhibit a regular pattern of any sort. To see if it did,

[7] C. C. Cutler and C. F. Quate, "Verification of transit time reduction of noise," *Phys. Rev.*, vol. 80, pp. 875–878; December 1, 1950.

Cutler and Quate built the apparatus illustrated in Fig. 13. In this device a cavity resonator provided with a coaxial output could be slid along an electron beam inside the vacuum, and the noise current could be measured along the beam. Fig. 14 shows the results they obtained and published in 1950. The experimental curve of noise versus distance does indeed rise and fall. The wiggles in the experimental curve have been attributed, probably correctly, to scallops or bulges in the diameter of the beam, which made the coupling of the beam to the resonator vary with distance along the beam.

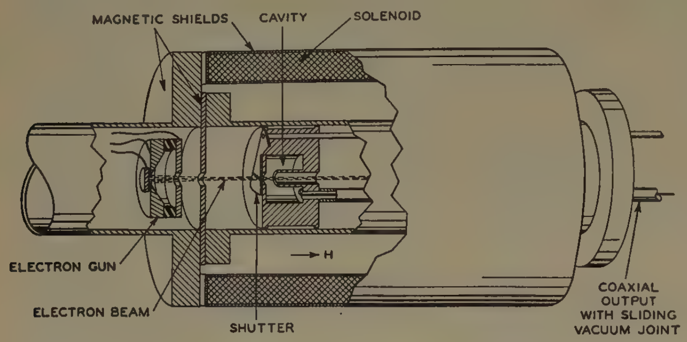


Fig. 13—The apparatus used by Cutler and Quate in measuring the noise current along an electron beam. The gun is located at the left. The beam passes through a resonant cavity which can be slid along so that the noise current can be picked up and measured as a function of distance along the beam.

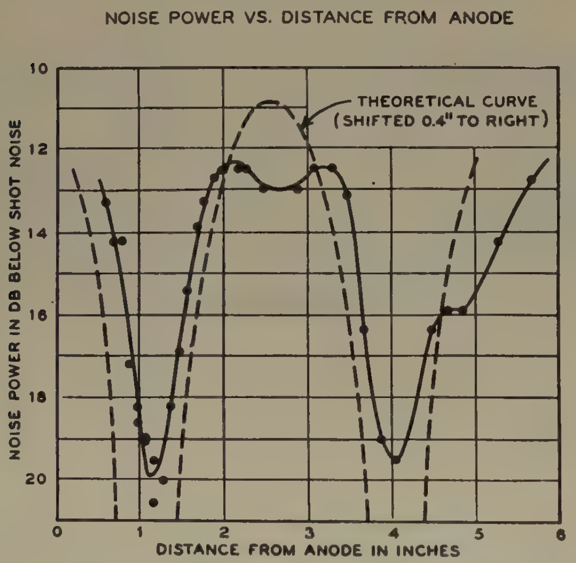


Fig. 14—A measured noise current along the beam (solid line) compared with the calculated noise current (dashed line). The measured curve departs from the theoretical curve in two respects: (a) the measured curve has small wiggles, which are attributed to a variation with distance of coupling between the beam and the resonator because of the scalloped outline of the beam; (b) the measured noise does not go to zero. Neither does the theoretical noise when the effect of current fluctuations as well as velocity fluctuations at the cathode is taken into account.

Not only did the results of Cutler and Quate correspond qualitatively with the theory, but the noise at the maxima was very close to the calculated value. The simple theory said that the noise at the minima should be zero. This was not so in the experiment. Only lately have we come to some understanding of this. Nonetheless, the experiment of Cutler and Quate marked a big step forward in the understanding of noise in microwave tubes. After it, there was every reason to believe that the simplified theory of noise in electron beams which had been proposed was trustworthy, despite its rather startling predictions. As soon as people believed this, they began having ideas based on the theory.

The first suggestion was merely that the electron gun be placed some critical distance from the beginning of the helix,[6] and indeed, by doing this, the noise figure of a traveling-wave tube was improved somewhat. The really startling improvement came, however, with an idea of D. A. Watkins, velocity-jump noise reduction. This was later found to be a special case of space-charge-wave amplification, which was reported by Field, Tien, and Watkins in 1951.[8]

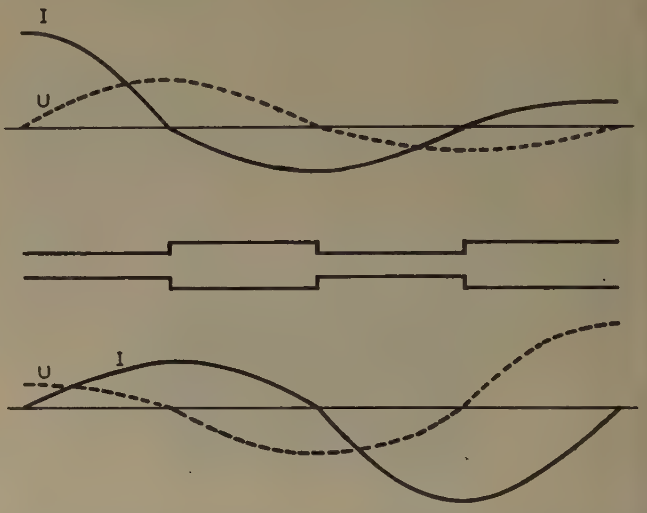


Fig. 15—This figure illustrates the principles of space-charge-wave or velocity-jump amplification. A standing wave pattern exists on a medium (center) of periodically varying impedance, as, for instance, a transmission line in which the conductors are alternately close together (low impedance) or farther apart (high impedance). If the lengths of the sections of low and high impedances are properly chosen, a standing wave pattern will either increase or decrease with distance along the circuit, as shown above and below, depending on whether $I$ is maximum or zero at the left, where the first low-impedance section begins. $I$ and $U$ can be interpreted as current and voltage in the case of a transmission line, or as convection current and a parameter—$u_0v/(e/m)$ in the case of the electron beam. Here $u_0$ is average beam velocity, $v$ is ac velocity and $e/m$ is the charge-to-mass ratio of the electron, taken as a positive quantity.

Consider Fig. 15. Imagine a number of sections of transmission line of alternately low impedance (represented by lines close together) and high impedance (represented by lines farther apart), each section a quarter wavelength long. A standing wave pattern of current $I$ and voltage $U$ along such a circuit increases or decreases with distance, as sketched above and below the circuit, depending on the phase; whether the current is zero or a maximum at the beginning of the circuit. We can easily see why the voltage and current patterns are as shown. Where a low-impedance line joins a high-impedance line, the current $I$ and the voltage $U$ are the same on each side of the junction, but $dI/dz$ is larger on the low-impedance side than on the high-impedance side, while $dU/dz$ is larger on the high-impedance side than on the low-impedance side.

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[8] L. M. Field, P. K. Tien, and D. A. Watkins, "Amplification by acceleration and deceleration of a single-velocity stream," Proc. I.R.E., vol. 39, p. 194; February, 1951.

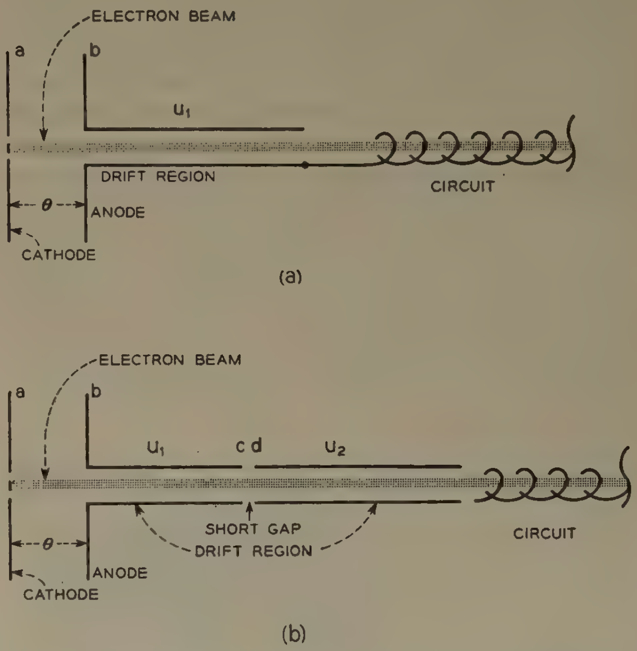
A signal on an electron beam can be regarded as made up of two waves, as is a signal on a transmission line. In the case of the transmission line the two waves travel in opposite directions. In the case of the electron beam, both waves travel in the direction of electron flow, but with different velocities. In the case of the waves on the electron beam, the quantity analogous to the current is the electron convection current, which we will call $I$. The quantity analogous to voltage we will call $U$; it is

$$U = -\frac{u_0 v}{e/m}\cdot$$

Here $u_0$ is the average electron velocity, $v$ is the ac velocity fluctuation, that is, the velocity modulation, and $e/m$ is the charge-to-mass ratio of the electron, a positive quantity. The characteristic impedance of the beam for the waves, that is, the ratio $U/I$ for a wave, depends upon the beam current and geometry and upon the dc voltage. The impedance is high for high voltages and low for low voltages. Hence, by varying the voltage periodically along the electron beam, that is, by jumping it up and down, phenomena analogous to the transmission line behavior illustrated in Fig. 15 can be achieved. As in the transmission-line case, $I$ and $U$ do not change where the impedance changes (through a change in dc voltage), but $dI/dz$ and $dU/dz$ do. Indeed, we can regard Fig. 15 as illustrating the behavior of the electron convection current $I$ and of the voltage-like parameter $U$ along a beam which travels through regions of higher and lower potentials, the regions being of particularly chosen lengths.

Having reached this point, we should remember that the Cutler and Quate experiment showed that the noise on the electron beam is a standing wave. Thus, this noise can be either amplified or deamplified by a velocity-jump structure such as we have been discussing. Whether it is amplified or deamplified depends upon just how far we put the gun from the structure, that is, on whether the standing-wave pattern has a current maximum or a voltage maximum where the electron beam enters the structure. By using such a structure, it should be possible to reduce the noise in a traveling-wave tube.

In 1952, Watkins published his results in reducing noise figure by use of a single velocity jump.[9] In Fig. 16, *a* illustrates the input end of a traveling-wave tube without a velocity jump. Here we have a cathode and anode, and a drift region of length adjusted to give a minimum noise figure. In *b* of Fig. 15 we have the input region of a traveling-wave tube with velocity-jump noise deamplification. The cathode and anode are followed by a drift region of such length that at point *c* the noise convection current is zero and the ac velocity of the noise and the corresponding "voltage" $U$ are at a maximum. At this point the average velocity, which we called $u_0$, is jumped from a low value $u_1$ to a higher value $u_2$ by means of an accelerating voltage. Across this jump, $U$ is constant; as the average velocity is made greater the ac velocity must be reduced. The noise standing-wave pattern to the right of *d* is smaller in amplitude than that to the left of *c*. From *d* the beam travels a critical distance to the helix through a drift region whose length is adjusted for minimum noise figure. With such a tube Watkins got a noise figure of 10 db at a wavelength of 10 centimeters.



(a)

(b)

Fig. 16—The noise figure of an ordinary traveling-wave tube, as shown in (a), can be optimized by adjusting the length of the drift region between the gun anode and the circuit. The noise can be further reduced by increasing the beam voltage, and hence the electron velocity, at the point beyond the gun anode at which the convection current of the noise standing-wave pattern is zero and the velocity modulation is a maximum. The beam should then pass along a drift region for some particular optimized distance, then finally enter the helix.

Subsequently, very careful work by Peter[10] pushed the noise figure at 10 cm down to around 8 db. Further work at the Bell Telephone Laboratories has resulted in noise figures of around 6 db at 3,000 megacycles and 8 db at 6,000 megacycles. The noise figures quoted are best noise figures, for in some tubes of a given type the noise figure is somewhat higher.

The tubes I have described use a single velocity-jump, while in explaining space-charge-wave amplification and deamplification in connection with Fig. 15 we considered the case of many jumps. Why not use many jumps and deamplify the wave much more, thus achieving an even better noise figure? The answer is that this won't work, for a reason which is now understood. The noise standing-wave pattern has two components, one arising from velocity fluctuations at the cathode and the other from current fluctuations at the cathode. Space-charge-wave deamplification reduces a standing wave pattern that has just the right phase at the start, as we have seen in connection with Fig. 15, but it increases the pattern if the initial phase is changed. We can deamplify the noise due to the velocity fluctuations to any degree we wish, but as we do this we amplify the noise due to the current fluctuations. If we use too much deamplification we will increase the total noise instead of reducing it, and that is what happens when one tries to use more than one velocity jump. Nonetheless, even one jump has taken us a long way, for we now have extremely good noise figures in microwave tubes.

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[9] D. A. Watkins, "Traveling-wave tube noise figure," Proc. I.R.E., vol. 40, pp. 65–70; January, 1952.

[10] R. W. Peter, "Low-noise traveling-wave amplifier," *R.C.A. Rev.*, vol. 13, pp. 345–368; September, 1952.

Before leaving the subject of noise it would be wise to note that much has been left out of this discussion, but I believe that what has been said does illustrate a useful achievement brought about through seeking and attaining a thorough understanding of a particular problem. However, much remains to be done in reducing the noise of traveling-wave tubes. The behavior of the electron stream near the cathode is not fully understood. There the thermal velocities do not form a small additional velocity component, as they do elsewhere in the electron stream, but constitute the whole electron velocity, and for this reason certain approximate calculations which are valid elsewhere in the electron stream do not apply near the cathode. Too, because of thermal velocities a potential minimum is formed near the cathode, at which electrons are turned back, and the r-f behavior of noise fluctuations at the potential minimum has not been treated satisfactorily. Thus, the limitations on noise figure of velocity-jump tubes have not been fully evaluated.

Further, several ideas other than velocity-jump or space-charge-wave deamplification are being worked on, so that it looks as if, in one way or another, the noise figure of traveling-wave tubes will be pushed progressively lower. The appropriate time to review such matters, however, will be when something substantial has been accomplished.

Much the same techniques which have been used in reducing the noise figure of traveling-wave tubes can be used in reducing the noise figure of klystron amplifiers, and we may expect to hear of progress in this direction.

The next advance which I wish to discuss concerns the focusing of electron beams. In the early days of the traveling-wave tube art one might typically start out with a cathode current at 10 milliamperes in a beam nominally $\frac{1}{8}$ inch in diameter and find that after the beam traversed a helix with an inside diameter of $\frac{1}{4}$ inch, only half of the current arrived at the collector, despite the use of a magnetic focusing field. Through improvements in the understanding of magnetic focusing with uniform fields we can now focus beams of several tens of milliamperes with a loss of only a few per cent or, if sufficient care is used, a few tenths of one per cent of the current.

When beams of comparatively large currents are to be focused, one almost always uses Brillouin flow.[11] In attaining this flow, a parallel beam of electrons is injected abruptly into a uniform field, as shown schematically in Fig. 17. Here we have to the left a concave, axially symmetrical cathode $C$, a cathode-potential beam-forming electrode $F$, and an apertured anode $A$ held positive with respect to the cathode. The anode also acts as a magnetic pole piece. To the right of the anode we have a uniform magnetic field; the fine solid lines indicate the lines of force. The field diverges in the region of the aperture, and the lines of force end on the pole piece or anode as shown.

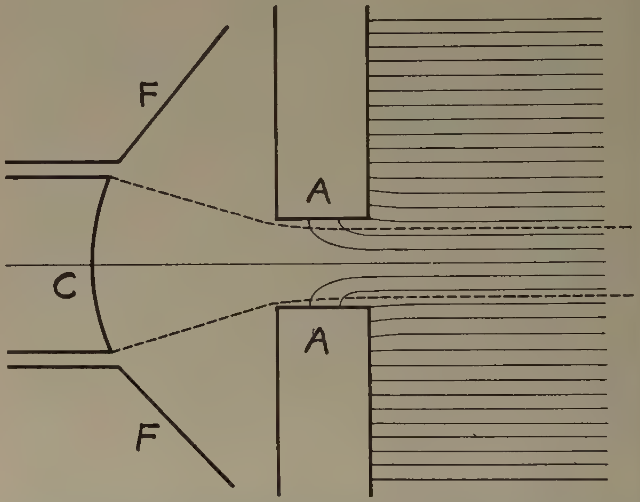

Fig. 17—In order to obtain Brillouin flow, a parallel electron beam is injected abruptly into a constant longitudinal magnetic field of the proper strength. The fine solid lines show magnetic lines of force. The dashed lines indicate the paths of the outer electrons of the beam. In entering the field, the electrons cut radial lines of force and are set whirling about the axis. The whirling through the longitudinal field produces an inward force which just counteracts the outward force due to space charge, plus centrifugal force.

In Fig. 17 the dashed lines indicate the paths of the outer electrons of the electron beam. As the electrons move along these paths into the magnetic field, they cut the magnetic lines of force in the vicinity of the aperture, and this sets the electrons whirling around the axis. Thus, in the uniform magnetic field they describe helical paths about the axis. The angular component of motion about the axis causes the electrons to cut the longitudinal magnetic field in such a way as to produce a force inward, toward the axis. If the electron velocity imparted by the accelerating voltage, the beam diameter, the beam current and voltage, and the magnetic field are in the proper relation, and if the electrons are injected into the field in the proper direction, the inward force due to the cutting of the magnetic field in the circumferential motion of the electrons just balances the outward space-charge force and the centrifugal force, and the beam maintains a constant diameter as it travels along in the field.

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[11] J. R. Pierce, "Theory and Design of Electron Beams," Second Edition, D. Van Nostrand Co.; 1954.

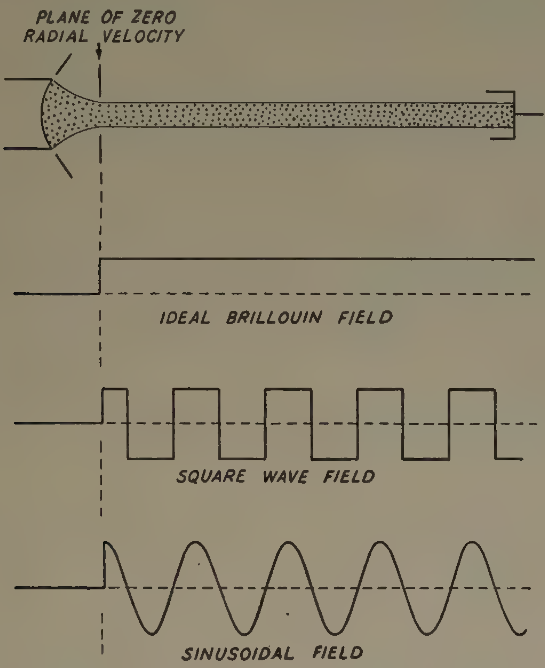

Fig. 18—At the top an electron beam focused by Brillouin focusing is shown, and below the variation of magnetic field with distance is plotted. An equal focusing effect can be obtained by a square-wave field (third from top) of the same peak amplitude as the Brillouin field. The electrons would whirl in opposite directions in regions of oppositely directed field. A sinusoidal field (bottom) will give the same focusing effect if its mean square value is equal to the Brillouin field. Periodic fields, however, will not focus if the period is made too long.

An electron beam flowing through a uniform magnetic field is illustrated schematically at the top of Fig. 18. Immediately below, the strength of the axial magnetic field is plotted vs distance along the beam. Ideally, the field rises abruptly as the electrons leave the gun and it is maintained at a constant value along the beam. What would happen if the magnetic field had a constant magnitude, but periodically reversed in sign, as shown third from the top? Actually, an abrupt reversal in direction of the magnetic field is physically impossible, but this condition can be approached. In the region of reversal of field there will necessarily be a radial fringing field. As an electron at a given radius passes through the region of reversal of field, the direction or sense of its rotation about the axis will be reversed. After the reversal, the inward force will still be the same, and so the idealized square-wave field will have just as much focusing effect as a constant field of the same amplitude.

Indeed, it can be shown that any periodic field, for instance, the sinusoidal field shown at the bottom of Fig. 18, has a focusing effect. If the periods are not too long, the sinusoidal field will focus properly when it has an rms value equal to the constant or Brillouin field which would be required. There is one catch, however, If the period is made longer, or if the beam current is increased and the strength of the field is increased to make up for this, a point will be reached beyond which focusing will not occur, but rather, the electron beam will diverge. This happens because the fluctuations in radius forced by the periodic nature of the field accumulate or grow when they have a special relation to the period of the oscillations in over-all beam diameter which would occur if the beam were started at a slight angle to the field.[11–14]

We see that an electron beam can be focused by means of a periodic field rather than a uniform field, but nothing has been said to indicate why this might be desirable. Indeed, work on the problem was inspired by the announcement of strong focusing in connection with nuclear accelerators, and initially there was no clear idea what the advantage might be. Strong focusing is indeed periodic in nature, but it has one other feature as well. In strong focusing as it is usually understood, the electrons are focused by a series of regions. In a plane through the path of the electrons the regions alternately act as equal converging and diverging lenses, and it turns out that such a sequence of lenses has a net focusing effect. After the possible use of such alternately converging and diverging focusing fields in connection with microwave tubes had been investigated, the idea of using a series of magnetic lenses, all of them converging, was hit upon, and its advantage was appreciated.

The advantage is illustrated in Fig. 19. At the upper

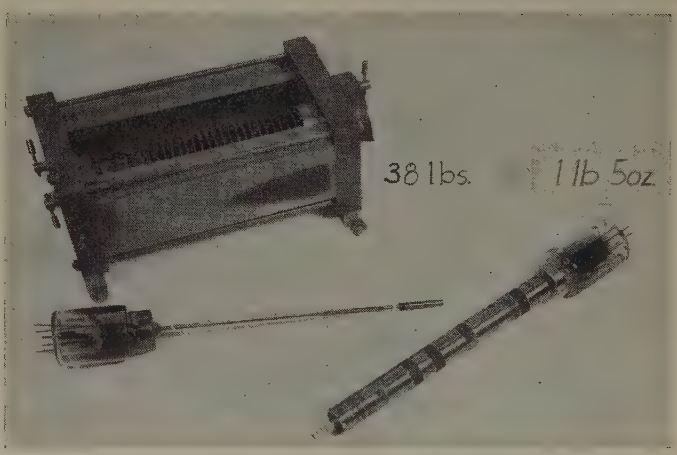

Fig. 19—A permanent magnet which will give the uniform field required to focus the traveling-wave tube shown weighs 38 pounds. A periodic focusing structure with the same focusing effect weighs only 1 pound and 5 ounces. The weight of the magnetic material required is proportional to the square of the field strength (which has the same average value along the axis in each case) times the volume occupied by the field. The field spreads out much more when it must be in the same direction for the whole length of the tube, and this accounts for the larger weight required in the case of the uniform field.

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[12] J. R. Pierce, "Spatially alternating magnetic fields for focusing low-voltage electron beams," *Jour. App. Phys.*, vol. 24, p. 1247; September, 1953.

[13] A. M. Clogston and H. Heffner, "Focusing of an electron beam by periodic fields," *Jour. App. Phys.*, vol. 25, pp. 436–447; April, 1954.

[14] J. T. Mendel, C. F. Quate, and W. H. Yocom, "Electron beam focusing with periodic permanent magnetic fields," Proc. I.R.E., vol. 42, pp. 800–810; May, 1954.

left this figure shows a permanent magnet which produces a uniform field for focusing the beam of a particular traveling-wave tube shown below it. The magnet weighs 38 pounds. The smaller magnetic structure shown at the lower right, with a tube in it, produces a periodic field of the same rms value, which focuses the electron beam just as effectively, but this magnetic structure weighs only 1 pound 5 ounces. The big advantage of periodic focusing lies in the reduction of magnet weight. This can be particularly important, for instance, in the case of tubes for airborne equipment. How does this improvement come about? We can see in several ways.

Consider, for instance, a permanent magnet structure which produces a uniform field over a distance of 1 inch. Suppose that we have made this as light and economical as possible. How can we modify this structure to produce a uniform field of the same strength over a distance of 2 inches? We can do this by increasing all its linear dimensions, including the dimensions of the magnetic material, by a factor of 2. This, of course, increases the weight by a factor of 8. Can we not simply take two 1-inch structures and set them end to end, with the fields they produce pointing in the same direction, and so obtain the same field strength over 2 inches? We cannot, because the presence of one tends to reduce the field across the gap of the other. We can, however, put them end to end and get, if anything, a slightly increased field, provided that the fields produced by the two are in opposite directions. The consequence is that to double the length of the field and have the field all in the same direction requires an eightfold increase in weight, while to double the length of field and get sections of equal strength but opposite directions requires only doubling the weight. In general, if the field is divided into $n$ alternating sections we can theoretically reduce the magnet weight by a factor $1/n^2$.

There is another way of seeing why the periodic field requires less magnet weight for a given rms field along the axis of the tube than does a uniform field. In a properly designed magnet, the weight of magnetic material required is proportional to the square of the field strength times the volume occupied by the field. To produce a long uniform field requires two pole pieces, north and south, which are far apart, and from these the field spreads out over a large volume, although we use it only over a narrow region near the axis. A periodic field can be produced by a large number of alternately north and south pole pieces. A little way off the axis, we see north and south poles at about the same distance, and hence, the magnetic field at a point away from the axis is very small. Thus, although the field may have the same mean square value on the axis, the volume over which the field extends has been greatly reduced, and so has the required weight of magnetic material.

Periodic focusing is clearly understood theoretically and it has been demonstrated experimentally, but it has not been applied commercially. The next big step will be taken when a tube using periodic focusing is designed for some particular application in which the light weight and absence of stray magnetic fields characteristic of periodic focusing make its use highly advantageous.

So far we have considered several sorts of advance in the field of microwave tubes: the sort of advance which is made in finally developing tubes of impressive performance for specific applications; the sort of advance one can make by building new circuits for existing tubes; and two important advances, in noise figure, and in focusing, made in connection with an existing sort of tube—the traveling-wave tube. As one final example, let us consider an advance in the form of a new idea, a new type of vacuum tube, a tube which can be tuned over wide ranges of frequency by changing the operating voltage.

Tubes of this general type, but of two different forms, have been described: the backward-wave oscillator, by R. Kompfner,[15] and the M-type carcinotron,[16–17] as described by Warnecke and Guénard of C.S.F.[18] Here we will deal primarily with the backward-wave oscillator, as described by Kompfner and others.[15,19]

In explaining the operation of a traveling-wave tube, we noted that the electron beam travels along in the same direction as does the wave on a slow-wave circuit, so that an electron which at one moment sees an accelerating field, sees the same accelerating field for a considerable time thereafter. This cumulative interaction between the electrons and the field is essential in the operation of the traveling-wave tube. The same sort of cumulative interaction can be obtained, however, even when electrons travel in a direction opposite to that of the wave, provided that the electrons see the wave only periodically.

Consider, for instance, the structure shown in Fig. 20. Here we have a waveguide built in serpentine form and pierced by axial holes through which the electron beam flows. The electron beam flows from left to right, while the wave travels from right to left. Consider an electron traversing the waveguide for the first time, at the far left-hand end. Suppose, for instance, that the wave in the waveguide has its peak accelerating value at this time and place. Consider then what happens when the same electron traverses the waveguide the next time, at the next fold. We can easily see that if the velocity of the electron bears the proper relation to the velocity of the wave, the electron can experience maximum acceleration again on this second traversal. This will happen if it encounters a later crest of the wave in the waveguide, which arrives at the second aperture just the right time after the earlier crest arrived at the first aperture. In fact, a given electron can see a peak accelerating field each time it crosses the guide. When this is so one finds that oscillations are generated. Power flows from the waveguide at the left-hand end, where the electrons from the gun flow in. The wave traveling to the left modulates and bunches the electron beam, and the electron beam in turn acts as a feedback path in traveling to the right. Thus, the wave excites the beam, while the beam excites a wave, which flows from the right-hand portion of the waveguide to the left. Oscillation does not depend on any resonance in the guide. The tube will operate if the waveguide is terminated in its characteristic impedance at both ends, so that there can be no wave traveling through the guide in the direction of electron flow.

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[15] R. Kompfner and N. T. Williams, "Backward-wave tubes," Proc. I.R.E., vol. 41, pp. 1602–1611; November, 1953.

[16] Pierre Guénard, Oskar Doehler, Bernard Epsztein, and Robert Warnecke, "Nouveaux tubes oscillateurs à large bande d'accord électronique pour hyperfréquences," *Acad. des Sci., Comptes Rendus*, vol. 235, pp. 236–238; July 21, 1952.

[17] R. Warnecke and P. Guénard, "Some recent work in France on new types of valves for the highest radio frequencies," *Proc. I.E.E.*, vol. 10, pp. 351–362; November, 1953.

[18] There has been some discussion concerning the history of the backward-wave oscillator and of the carcinotron. During the IRE-AIEE Electron Tube Conference at Ottawa in June, 1952, R. Kompfner described a backward-wave oscillator which tuned electronically from 6.0 mm to 7.5 mm, and B. Epsztein described a centimeter-range M-type carcinotron with several watts power and a 30% electronic tuning range. The French term "O-type Carcinotron" is equivalent to "backward-wave oscillator" as used in this paper.

[19] P. K. Tien, "Bifilar helix for backward-wave oscillators," Proc. I.R.E., vol. 42, pp. 1137–1143; July, 1954.

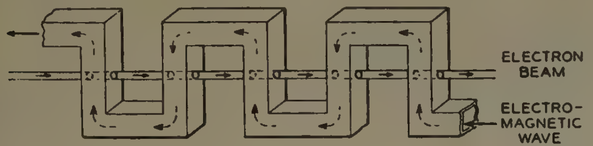

Fig. 20—An electron beam and a wave can interact cumulatively even when the wave and the electrons travel in opposite directions, provided that the electrons see the wave for short times only, periodically. Here we can see that an electron which crosses the waveguide for the first time when the field is accelerating may also be accelerated on its second crossing of the waveguide if a new wave crest arrives at the point of crossing just as the electron does. Such cumulative interaction results in oscillation at the frequency at which the interaction is cumulative. This frequency changes as the operating voltage is varied, changing the electron velocity.

The cumulative interaction between electrons and wave requires a critical relation between the electron velocity, the space between points at which the electron crosses the waveguide, and the speed and wavelength of the wave in the waveguide. What happens if we change the electron speed, so that the critical relation no longer holds at a particular frequency? The relation will hold at some other frequency, at which the wavelength and the speed of the wave in the guide are different, and so the frequency of oscillation shifts. Fig. 21, in fact, shows a plot of frequency of oscillation in kilomegacycles per second versus electron beam potential in volts. In the range from 700 volts to 2,300 volts, the frequency shifts from about 45,000 mc to about 63,000 mc; that is, from a wavelength of 6.7 mm to a wavelength of 4.8 mm. This gives a tuning range of 37 per cent, or 18,000 mc, a frequency range as great as the bandwidth of all radio waves of wavelengths longer than 1.7 cm. This tuning range is covered without any mechanical motion, merely by changing the voltage of operation.

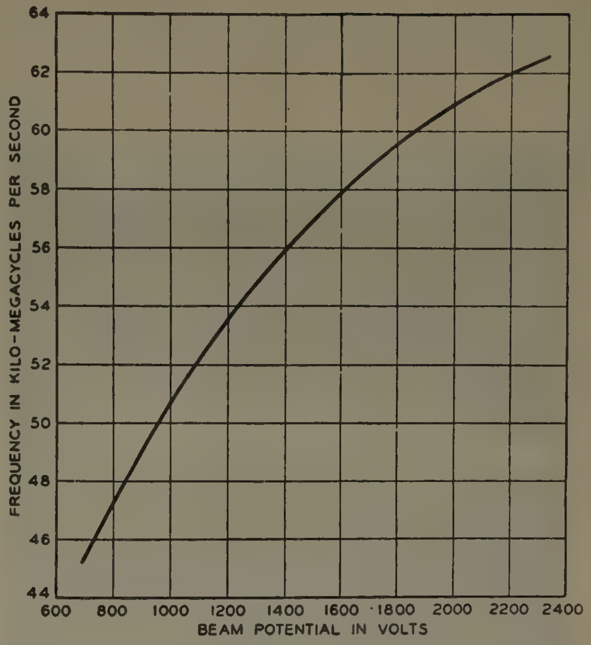

Fig. 21—A plot of frequency versus voltage for a backward-wave oscillator built by Kompfner. This tube tunes electronically over a range of frequencies greater than the entire bandwidth of wavelengths longer than 1.7 cm.

It is clear that the parts of a backward-wave oscillator for such a frequency range must be very small. Indeed, while the circuit used is in principle much like that shown in Fig. 20, the physical structure is somewhat different. The circuit is composed of two arrays of hairpin-like loops of wire, made by winding wire on a mandrel and then dissolving out the mandrel. One such array is shown in Fig. 22. The taper at the end is used in match-

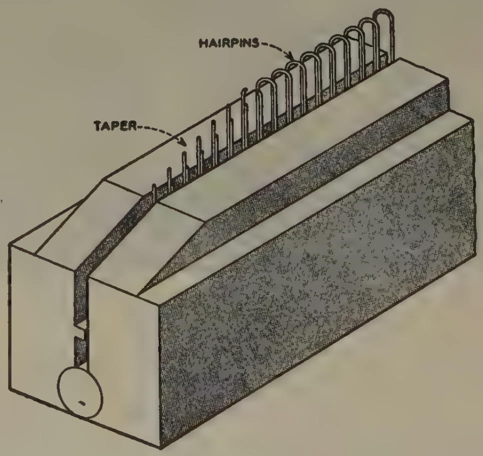

Fig. 22—The serpentine structure in the millimeter wave tube is made by interleaving two arrays of hairpin-like loops of wire, so that there is a serpentine path between the loops. These loops of wire are brazed to the top and bottom walls of a waveguide. At the ends of the arrays, the loops are cut away along a taper so that the interleaved structure is tapered gradually to an ordinary rectangular waveguide.

ing the circuit to a rectangular waveguide. Fig. 23 shows an X-ray photograph of two such arrays, interleaved so that there is a serpentine path between them. It is in this serpentine path that the wave travels, just as in the serpentine waveguide of Fig. 20. The tapered portions of the arrays, as shown in the lower part of Fig. 23, are used to transform the circuit gradually into a waveguide suitable for a power output connection. Fig. 24 shows a picture of an experimental millimeter oscillator made by Kompfner.

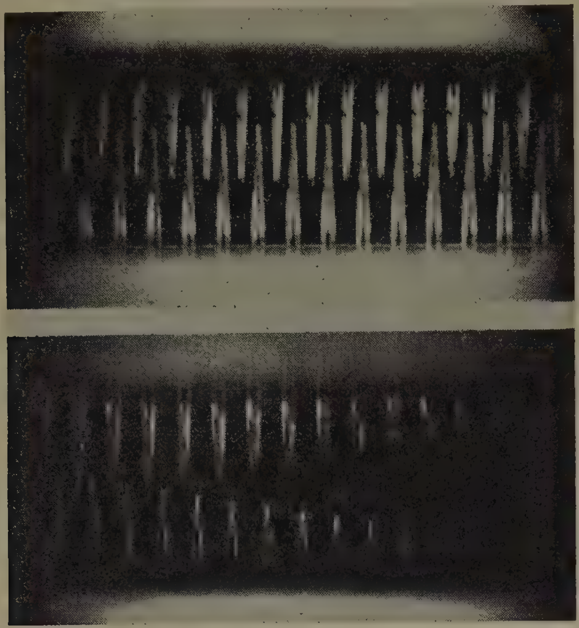

Fig. 23—This figure is an X-ray photograph showing the interleaving of the hairpins of Fig. 22 to give the serpentine path along which the wave travels. The tapering of the hairpins to match the circuit to ordinary rectangular waveguides is shown at the bottom.

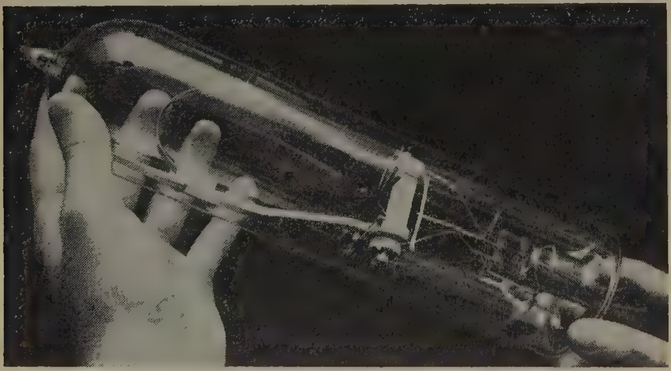

Fig. 24—The assembled millimeter-wave oscillator using the hairpin structure.

Backward-wave oscillators seem particularly advantageous in generating millimeter waves, because mechanical tuning, which can be very troublesome in connection with minute structures, is entirely avoided. Karp and Yocom, at Bell Laboratories, have made backward-wave oscillators somewhat different from Kompfner's. A tube for use from 5–6 mm is shown in Fig. 25. Backward-wave oscillators have many other potential uses and advantages as well, however. Putz at Stanford has produced around 100 watts with an efficiency of around 10 per cent in wavelength range around 10 cm with a backward-wave oscillator using a serpentine structure. Sullivan at the Bell Laboratories has made a backward-wave oscillator using a somewhat different circuit; this tunes continuously from 2,700 to 13,000 mc, a tuning range of 5 to 1. A variety of other backward-wave oscillators suitable for test gear and other applications have been made.

The M-type carcinotron was mentioned earlier as a tube which operates much the same as does the backward-wave oscillator. The fundamental difference is that in the M-type carcinotron the electrons flow not in a region of constant potential, guided by a longitudinal magnetic field, as they do in klystrons and traveling-wave tubes, but they flow in a region of crossed electric and magnetic fields, both fields perpendicular to the direction in which the wave travels along the circuit and to the average direction in which electrons progress along the circuit. This flow in crossed electric and magnetic fields is like the flow of electrons in a magnetron. Carcinotrons have been made largely for operation at high powers in the longer cm wavelength range. The powers and efficiencies attained appear to have been substantially higher than those for backward-wave oscillators. Powers up to 200 watts in the frequency range 2,000–3,000 mc have been cited.[20] However, it seems that at very short wavelengths it is easier and more practical to use focusing with a longitudinal magnetic field than it is to achieve suitable electron flow in crossed electromagnetic fields.

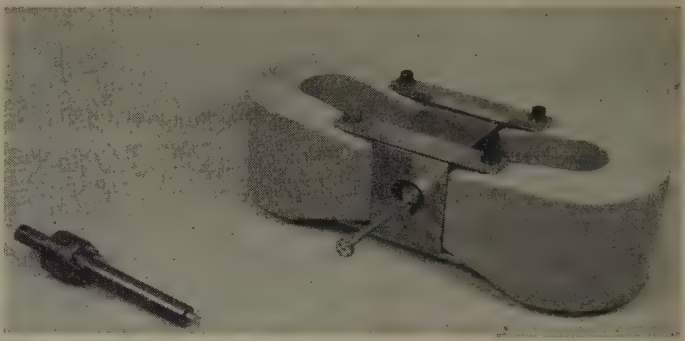

Fig. 25—Another form of millimeter wave backward-wave oscillator due to A. Karp and W. H. Yocom. The circuit in this tube is an array of resonant wires or tapes obtained by winding tape over a mandrel which has in it a groove approximately one-half wavelength wide. A tube is shown, together with a tube in a suitable permanent magnet.

The current problem in connection with backward-wave oscillators and carcinotrons lies not so much in how to make a tube of specified performance as it does in uncovering the applications in which these tubes will have substantial advantages over other types of tubes, and in choosing from among circuits and constructions which have been considered those which are best suited to the applications.

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[20] E. Dench, "A voltage tuned high power microwave oscillator," *Proc. of the National Electronics Conference*, vol. 9, pp. 445–456; February, 1954.

This survey, which has ranged from newly developed tubes of an old type to tubes of an entirely new type has, as was indicated earlier, failed to mention a number of interesting advances in microwave tubes. Some of these, such as the resistive-wall amplifier[21] and the double-stream amplifier,[5] were omitted because they seemed of less practical importance than, for instance, the space-charge-wave amplifier. I have given a simple description of the operation of these and some other tubes elsewhere.[22] Some advances, such as those being made currently in the field of high-power traveling-wave tubes, are difficult to talk about because the state of the work is perhaps not far enough advanced to make an adequate judgment and comparison of various approaches. Some advances of very considerable importance, such as the counter-wound helix and various other varieties of circuits for traveling-wave tubes and backward-wave oscillators, have not been mentioned because their appeal is largely to specialists in the tube field. The bibliography which follows may help in directing those who wish to pursue such matters to a number of sources of information.

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[21] C. K. Birdsall, G. R. Brewer and A. V. Haeff, "The resistive-wall amplifier," Proc. I.R.E., vol. 41, pp. 865–875; July, 1953.

[22] J. R. Pierce, "The wave picture of microwave tubes," *Bell Syst. Tech. Jour.*, vol. 33, pp. 1343–1372; November, 1954.

# A Design Philosophy for Man-Machine Control Systems*

H. P. BIRMINGHAM† MEMBER, IRE, AND F. V. TAYLOR†

**Summary—Empirical evidence suggests that, at least for short periods of activity, the simpler the tasks imposed upon the human operator of a control system, the more precise and less variable become his responses. This leads to the view that optimal man-machine control system performance can be obtained only when the mechanical components of the system are designed so that the human need act only as a simple amplifier. Ways and means are described for achieving such design through "unburdening" (relieving the operator of the task of acting as an integrator) and "quickening" (providing the operator with immediate knowledge of the effects of his own responses). Aided tracking is discussed in light of these two concepts and is related to various efforts to improve the stability of man-machine systems through the use of special equalization networks.**

## The Concept of a Man-Machine System

THE CARDINAL purpose of this report is to discuss a principle of control system design based upon considerations of engineering psychology. This principle will be found to advocate design practices for man-operated systems similar to those customarily employed by engineers with fully automatic systems. Admittedly, the reasoning leading to the principle is largely speculative, but the successes which have already been attained in following it seem to warrant a hopeful attitude toward its future usefulness.

In many control systems the human acts as the error detector. Men play such a role in piloting aircraft, in steering ships, in controlling submarines in heading and depth, in driving tanks and automobiles and in tracking with gun and missile directors. During the last decade it has become clear that, in order to develop control systems with maximum precision and stability, human response characteristics have to be taken into account. Accordingly, the new discipline of engineering psychology was created to undertake the study of man from an engineering point of view.

One of the by-products of engineering psychology is the conceptualization of the human operator and the machine which he controls as the two parts of one overall man-machine system. Fig. 1 shows a model of this concept.

The man is schematized by the boxes shown above the heavy black line, while components of the machine are blocked in below. In the human, three sets of organs or functions are important to man-machine system operation; these are the receptors, the central nervous system (CNS) and the effectors.

The receptors consist of the sense organs of the body; for example, special cells in the retina of the eye, the organs of Corti in the ear, and the proprioceptors in the muscles, tendons, and joints. It is through the receptor organs that changes in energy in the external environment take effect upon the human organism. Such energy changes which excite receptor cells are called stimuli (S).

Not only is the organism acted upon by environment—in turn man modifies the external world through responses (R) of the effector organs. In the human, effectors consist of muscles and glands, though only the former are directly involved in man-machine system function.

Between the receptors and effectors is shown the central nervous system, which consists of the brain and spinal cord. It is through the activity of this nervous system that thought, judgment and decision-making arise and learning takes place.

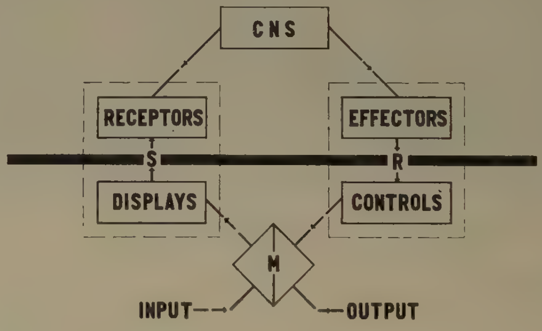

Fig. 1—The man-machine system.

Connecting the three uppermost boxes are lines which represent the peripheral nervous system, with the sensory nerves connecting the receptors to the central nervous system, and with the effectors being supplied by the motor nerves. The upper portion of the diagram may be interpreted as indicating that stimulation from the outside leads to nerve impulses going to the central nervous system, where they are re-routed along the motor nerves to the muscles. The latter respond, moving the body or applying force to some object and thus altering in some degree the state of the external world.

The only part of man's environment represented in the diagram is the machine, which is shown in the lower half of the figure. It is through the controls, the levers, knobs, handwheels and switches, that human response takes its effect upon the mechanism. On the other hand, it is through the displays, the dials, light panels, cathode ray tubes, horns, buzzers, and cross-pointer indicators, that the operator is presented with information concern-

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* Original manuscript received by the IRE, March 22, 1954; revised manuscript received, May 19, 1954. The opinions or assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department and the naval service at large.

† Naval Research Lab., Washington, D. C.

ing the activities of the mechanism, represented in the schema by the box labelled "$M$." Within the box are the vacuum tubes, the amplifiers, the special circuits, the servo motors, the electronic or mechanical computers and the power drives—in short, those parts of the system that traditionally interest the engineer most.

At the very bottom of the paradigm are shown the input and the output of the system. The nature of these two quantities depends, of course, upon the particular man-machine system under consideration. In an automobile-driver system, the input consists of successive positions along the twisting roadway, as visually apprehended, while the output is the progress of the car along the highway. In an anti-aircraft system, the input is the spatial course of the enemy aircraft sensed through optics or radar. The output, in this case, consists of voltages which position the guns so that the bullets will pass close to the target.

Taking the complete man-machine system to be a gun-pointing device, the informational flow is as follows: The position of the enemy aircraft is sensed, let us say, by radar. This information is processed at $M$ and displayed to the operator. The display might be such as to present the target as a dot on a cathode ray tube, seen against a centered cross line. The operator, having been instructed to track the target, observes the misalignment and manipulates a control to move the target onto the reticle. The control motion, when transformed by $M$, (1) changes the system output (it repositions the guns), and (2) if the human's response has been adequate, reduces the misalignment between the target and the cross line. However, since the input will continue to change, the operator will be forced continually to make control adjustments if he is to keep the misalignment at a minimum. This will have the effect of insuring that the output of the system at all times remains more or less appropriate to the input, i.e., that the guns will shoot in the general direction of the target. In the case of airplanes, tanks, radars, sonars, and the like, different inputs and outputs are involved, but the diagram fits equally well.

In general, it is the task of the engineering psychologist to assist the engineer in designing the displays, controls, and intervening mechanism, so that the output of the man-machine system is optimized, while the human operator requirements in regard to native ability and training are minimized. Specifically, this report will be confined to recommendations concerning the design of the circuits and equipments which define the task of the operator in a continuous control loop.

## Human Characteristics Relevant to Control Engineering

### *Vision—Man's Basic Input Channel*

Though, theoretically, several of the human senses could be made to serve as information channels through which the man could detect changes in the state of a controlled quantity, only vision and hearing have been utilized to any extent as primary inputs in control engineering. Furthermore, of the two senses, only vision has been employed frequently. This is principally the result of the fact that only the sense of sight permits both the direct and accurate apprehension of geometrical space as it extends outward beyond the confines of the body. This spatial quality underlies three of the following four properties of the visual sense, which are frequently exploited by control engineers:

*Acuity:* Though there are many different measures of visual acuity, those most relevant to continuous control and tracking tasks indicate that an operator with normal eyesight would have no difficulty in detecting a visual error of 0.3 mils real field.[1] If the target is viewed through an optical telescope, a magnification of only six power is needed to increase the visual resolution to 0.05 mils real field. Though loss of light through the lenses will attenuate this figure somewhat, the acuity will still be very high for control devices.

*Form Perception:* The ability to perceive visually and react to spatial configurations is found only in higher living organisms. For certain tasks requiring landmark or target recognition, the selection and tracking of one of many targets, and/or the direct identification of friend or foe, there is no adequate substitute for the human eye.

*Invulnerability to Confusion:* As a result of the high acuity and the ability to discriminate form, the visual sense is immune to certain confusions which affect radar performance deleteriously. Whereas to the eye, an aircraft is recognizably different from a cloud or rainstorm, this is not always so with radar.

*Invulnerability to Electronic Jamming:* Though direct vision is limited to moderate ranges and to conditions of clear daytime visibility, it is immune to all forms of electronic jamming. This feature gains importance as electronic sophistication increases on the part of prospective foes.

### *Human Output*

*The Application of Force:* All human responses which are directly necessary to the functioning of man-machine systems are brought about through the synergetic contraction and relaxation of muscles attached to the skeleton in such a fashion that force is applied to one or more controls. Though man is one of the weakest of the higher animals, he can supply several hundred pounds of force with leg and back muscles for short periods of time when called upon to do so. The strength of the arms is considerably less, but even in this case, more than 50 pounds of pull can be applied with the arms in bursts without fear of over-taxing the organism.[2] Less is known about man's ability to graduate his force applications with precision than about the limits of his strength. However, evidence is available which shows that the *absolute* variability of an operator in reproducing pressures with aircraft-type controls increases as the pressures increase from one through 40 pounds, but that the *relative* variability decreases from one through 10 pounds and thereafter remains fairly constant.[3] Inferences from early lifted-weight experiments suggest that below one pound the precision of force control deteriorates very rapidly.[4]

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[2] "Handbook of Human Engineering Data for Design Engineers," Tufts College, USN Tech. Rep. No. SDC 199-1-1, Part 1–9; 1949.

*The Action of Force on Different Controls:* Analysis discloses that different controls, when acted upon by physical force, respond in ways which require different mathematical characterizations. Thus, if force is applied by whatever means to a spring-centered joystick, the angle through which the joystick is displaced is directly proportional to the magnitude of the applied force. This is true whether the restraining springs are relatively weak or so stiff that they permit practically no motion of the control, as is the case with a pressure joystick. With the latter, however, gain is markedly reduced from that which obtains when more motion is permitted.

In contrast to the action of a spring-centered control, a viscously damped joystick will respond to applied force by moving with an angular velocity proportional to the magnitude of the force. This means that, with this type of control, joystick displacement is proportional to the time integral of force.

Finally, if the damper is removed, inertia added and force applied, the joystick will exhibit an angular acceleration which will be proportional to the magnitude of applied force. With this control arrangement, joystick displacement becomes proportional to the second integral of force.

It is true, then, that zero, one or two integrations can be accomplished by the physical interaction between force and the control, depending upon whether spring-centering, viscous damping, or inertia, is the dominant characteristic of the control. Furthermore, the gain factors can be modified by adjusting (a) the sensitivity of the control pickoff, and (b) the amount of spring-centering in the first case, damping in the second and inertia in the third. In Fig. 2 are shown the block diagrams and equations for the responses to applied force of the three types of joystick.

In the equations, $\theta_0$ is to be taken as the amplitude of joystick displacement, while $\theta_i$ represents the amplitude of the force input as functions of time. One dot over a term indicates the first derivative with respect to time, and two dots the second derivative of the term. The $a$ represents a constant which may change in value from one equation to the next. In the figure, the triangles represent amplifiers of adjustable gain, and the square boxes labeled ($\int$) represent integrators.

*Force as Man's Output:* Introspective analysis suggests that the human regards his own basic output as limb displacement, at least for most situations. However, this cannot usefully be taken to be his output in the case where the control which he is manipulating is so tightly spring-restrained that it moves only a millimeter or two under maximal pressure. Under such circumstances it is convenient to take applied force as man's output. As a matter of fact, it seems reasonable to take applied force as the fundamental human output in all control systems, since, as Hick (1946) and Hick and Bates (1950), point out in their important papers, force must be applied to every control regardless of the particular transfer properties involved in any one situation.[5,6] Accordingly, human output will be equated with force throughout this report. This is done without any necessary implication that force is more "real" than displacement, or that this particular way of looking at human behavior will be especially productive if transferred from human engineering to theoretical psychology.

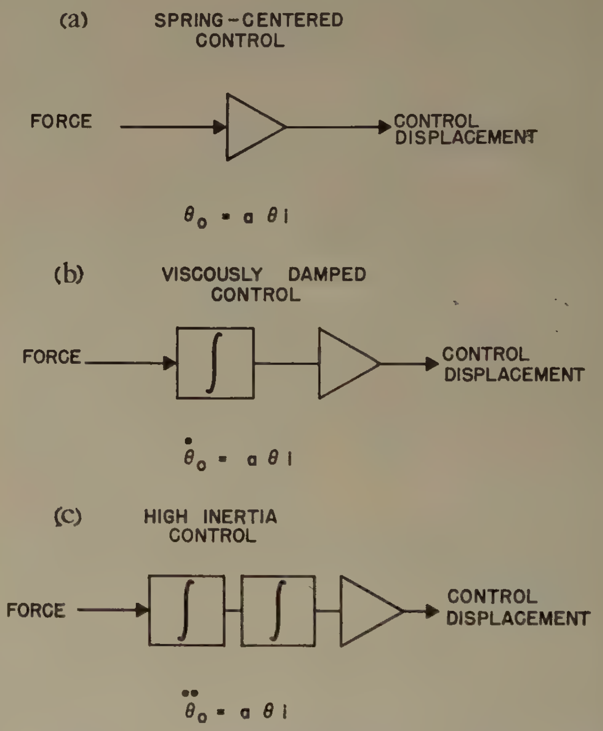

Fig. 2—The action of force upon three types of manual controls.

*Kinesthetic Feedback:* It should be pointed out that different control arrangements not only integrate force a varying number of times, but also affect qualitatively and quantitatively the information fed back from the kinesthetic receptors which signal the degree of activity of the moving limb's tissues. When a pressure joystick is being employed, the kinesthetic feedback contains only information relating to force or pressure, since no displacement is permitted by the control. However, with a moving joystick, the feedback pattern contains information about the displacement of the limb and, perhaps, even about the rate of displacement as well as stretch or pressure specifications. This might lead one to conclude that control with a pressure stick would be less accurate than with a joystick which moved.

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[3] W. O. Jenkins, "The discrimination and reproduction of motor adjustments with varying types of aircraft controls," *Amer. Jour. Psychol.*, vol. 60, pp. 397–406; 1947.

[4] R. S. Woodworth, "Experimental Psychology," Henry Holt and Co., New York, N.Y., p. 433; 1938.

[5] W. E. Hick, "The Effect of Heavy Loads on Handwheel Tracking," Medical Res. Council, SRI (Servo) Rep. No. 3; July 1, 1946.

[6] W. E. Hick and J. A. V. Bates, "The Human Operator of Control Mechanisms," Permanent Records of Res. and Dev. Mono. No. 17.204 (Great Britain); 1950.

But quite the opposite conclusion has been reached by Gibbs[7] who finds pressure control to be superior to displacement control. In explanation of this, he adduces physiological evidence to show that the kinesthetic information available during pressure control is greater in amount, more rapidly conducted, and more directly related to applied tension, than that arising from the manipulation of a displacement control. It would seem, however, that more evidence concerning these matters is still required before the issue of the absolute superiority of one type of control over another can be closed. This matter will be mentioned again later in this report.

### *Central Processes*

*Intermittency:* Whenever the human is called upon to respond to some transient in his sensory environment, a period of time elapses before any response is initiated. This pause before the starting of a response is called the reaction time, and though it varies widely from moment to moment, it averages around 250 milliseconds if any "choice" is required.

There are several different sources of evidence[8–12] which suggest that, as a consequence of the reaction time delay and other factors, human response is intermittent rather than continuous. It would seem that if any type of servo motor could be taken as an analog of human behavior, it would have to be an intermittently sampling servo, instead of a continuous follower. The available evidence points to a periodicity in man of about two responses per second, with a single response cycle taking 500 milliseconds or more and with this time fairly equally divided between the reaction time and the movement time. It appears that the organism utilizes the reaction time to "organize" the response which, once triggered, runs off to completion without direct voluntary control.

*Bandpass:* If the evidence on human response intermittency is accepted, it is possible to infer the highest input frequency which the man can successfully follow. Practical experience indicates that at least four samples per cycle are required to reproduce the waveform of the input with reasonable fidelity. If this is taken as a minimal figure, it follows that the human, responding on an average of twice per second, will be able to follow with some success, frequencies no higher than 0.5 cycle per second. Of course, the lower the input frequency, the more samples per cycle will be obtained, with the result that the fidelity of reproduction will increase as the input frequencies drop.

Translating cycles per second into radians per second, our inferences lead to the specification of the human bandpass as the region between zero and three radians per second.

*The Human Transfer Function:* It would be convenient for engineers if it were possible to write an equation which would represent the transfer function of the human in a man-machine system. With this transfer function available, it would then be possible, at least theoretically, to design the remainder of the system to complement the man's characteristics in such a way as to achieve high system precision and stability. Accordingly, several studies have been run in the attempt to characterize human tracking performance in mathematical terms. Perhaps the best known of these were carried out by Phillips (1943), Tustin (1947), and Raggazini (1948).[13–15]

Two difficulties stand in the way of obtaining any single useful equation representing man's input-output relationships. The first relates to the difficulty of providing an adequate mathematical treatment for an intermittent system, such as the human appears to be. Though it is possible to deal with a discontinuously sampling system in terms of nonlinear mathematics, it is extremely awkward and tedious to do so.[16] It is customary, therefore, to treat such intermittent systems in terms of the nearest linear approximation. This is done in the hope that, though the model chosen is recognized as being an imperfect analogy, it is still sufficiently appropriate to be useful. Following this convention, all expressions of the human transfer function to date have had the form of linear differential equations and, no doubt, this practice will continue. The final judgment as to the fruitfulness of thus approximating the intermittent by means of a continuous model must await the analysis of future experimental and pragmatic evidence.

But even more fundamental to the problem of writing an equation to express human input-output relationships is the fact that man appears to have many transfer functions. Evidence[17] suggests that, through learning, the human operator modifies his transfer function and alters his gains to suit the control task with which he is confronted. If the task requires an integration, he soon starts acting as an integrator, or if differentiation is called for, that also will be supplied. In short, the man alters his transfer properties in the direction of optimizing the performance of the man-machine system as it is communicated to him through the displays.

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[7] C. B. Gibbs, "The Continuous Regulation of Skilled Response by Kinaesthetic Feedback," Medical Res. Council, APU 190/53; March 1–13, 1953.

[8] J. A. V. Bates, "Some characteristics of the human operator," *Jour. IEE*, vol. 94, pp. 298–304; 1947.

[9] K. J. W. Craik, "Theory of the human operator in control systems. I: The operator as an engineering system," *Brit. Jour. Psychol.*, vol. 38, pp. 56–61; 1947.

[10] K. J. W. Craik, "Theory of the human operator in control systems. II: Man as an element in a control system," *Brit. Jour. Psychol.*, vol. 38, pp. 142–148; 1948.

[11] W. E. Hick, "Discontinuous functioning of the human operator in pursuit tasks," *Quart. Jour. Exp. Psychol.*, part 1, pp. 36–51; 1948.

[12] M. A. Vince, "Corrective movements in a pursuit task," *Quart. Jour. Exp. Psychol.*, part 1, pp. 85–103; 1948.

[13] H. M. James, N. B. Nichols, and R. S. Phillips, "Theory of servo-mechanisms," Radiation Lab. Series No. 25, McGraw-Hill Book Co., Inc., New York, N. Y., pp. 360–368; 1947.

[14] A. Tustin, "The nature of the operator's response in manual control and its implications for controller design," *Jour. IEE*, vol. 94, pp. 190–202; 1947.

[15] J. R. Raggazini, "Engineering aspects of the human being as a servo-mechanism," unpublished paper presented at meeting of Am. Psychol. Assn., 1948.

[16] B. Stafford, "Frequency Analysis of Some Closed-Cycle Sampled-Data Control Systems," NRL Rep. No. 3910; 1952.

This adaptability on the part of the man is, of course, a great boon to the control designer, since he can rely upon the human to make the most of any control system, no matter how inadequate. It is this which probably constitutes the most important single reason for using men in control loops. Yet, this very adjustability renders any specific mathematical expression describing human behavior in one particular control loop quite invalid for another man-machine arrangement. This suggests strongly that "*the* human transfer function" is a scientific will-o'-the-wisp which can lure the control system designer into a fruitless and interminable quest.

It would be better to recognize man's propensity for adaptation and to consider whether the human operator is equally precise when he adopts one transfer function as when he assumes different transmission properties. If it should turn out that this is not the case, it would then seem desirable to design the nonhuman elements of the control system so as to use the man in the role he is most competent to play.

Unfortunately, no direct scientific evidence is available to furnish guidance in this matter. However, empirical observations suggest that there are wide variations in man's ability to satisfy different equations and that, speaking mathematically, he is best when doing least. It becomes, therefore, a fundamental assumption of this paper that the more complex the human task, the less precise and the more variable becomes the man.[18] It is assumed that, within limits, the higher the number of integrations and/or differentiations required of the man, the poorer will he perform. Conversely, it is hypothesized that the more the human operator is freed from the tasks of integration and differentiation, the more regular and precise will become the human output. Human control behavior, it is asserted, reaches the optimum when the man becomes the analog of a simple amplifier as shown in the following equation:

$$\theta_0(t+\tau) = \theta_i(t) \qquad (1)$$

where $t$ represents a value in time, and $\tau$ equals the human reaction time.

## A Basic Principle of Control Design

In contrast to the poor performance of complex tasks hypothesized for the human operator is the fact that machines can be built to perform intricate computations with remarkably high precision and low variability. It is true that stability and accuracy are not obtained without effort, but for such tasks as double or triple integration and/or differentiation it seems unquestionable that electronic or mechanical components can be made to be more precise and repeatable than man.

If this is the case, and if precision is required, it follows that when a man-machine system must integrate, differentiate or perform other higher-order computations, these should be supplied by the nonhuman components of the system whenever possible. This is tantamount to saying that the human should be required to do no more than operate as a simple amplifier. Broadening this somewhat, adding to it a statement as to human bandwidth, and phrasing it as a general design principle, the following emerges: *Design the man-machine system so that (1) the bandpass required of the man never exceeds three radians per second, and (2) the transfer function required of the man is, mathematically, always as simple as possible, and, wherever practicable, no more complex than that of a simple amplifier.*

The remainder of this paper will consist of illustrations of ways of utilizing this principle, together with explanations of its efficacy in human engineering terms. However, two matters require general comment at this early point in the discussion. First of all, it is essential to describe a basic condition which must be observed if the ultimate intent of the design principle is to be achieved. Second, it is necessary to answer the obvious question of why, after designing the system so that only amplification is required of the man, one should not take the final step of dispensing with him entirely by substituting an actual amplifier in his place.

As to the first, in order to obtain optimum performance from the control system, it is necessary, not only to design the system so that amplification is all that is required of the operator, but it is also necessary to insure that the operator adopts this, and no other, mode of response. It appears that when placed in a control loop, the human goes through a trial-and-error process wherein he varies his transfer function until he achieves a condition of minimum average error as it is reflected to him via the display. It follows from this that to insure the adoption by the operator of a mode of action equivalent to simple amplification, it is necessary to so design the nonhuman components that the operator will achieve minimum error at the display when he acts as an amplifier. If, through inadvertence, the design of the control loop permits the operator to reduce the displayed error more by acting as an integrator, differentiator, or a combination of one or more of these than as an amplifier, then, most certainly, he will do so.

In regard to the question of why the design principle does not lead logically to employing an amplifier to supersede the man, one can only say that it does lead to precisely that—whenever it is feasible. Under some circumstances the best man-machine system design will demand the removal of the human from the system. But in many other circumstances it would be impractical to automatize completely.

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[17] L. Russell, "Characteristics of the Human as a Linear Servo-Element," unpublished M. S. Thesis, Servomechanism Lab., MIT; 1951.

[18] This assumption is made in relation to tracking and control systems employing "compensatory" type displays, since these are used preponderantly in practical man-machine systems. It is anticipated that some of these assumptions will require elaboration when they are applied to systems, such as may be constructed for laboratory use, where a "pursuit" ("match-the-pointer") display can be utilized.

For example, in cases where the operator tracks targets optically, his removal would require the substitution of radar, infra-red, or some other electronic sensing mechanism. In other situations, even though it might be quite possible to remove the man from the control loop, it would be deemed inadvisable to do so for safety reasons. It can be argued that whenever a man must be present as a monitor he should be used as a controller so as to make unnecessary the extra cost, added weight and increased maintenance load which complete automatization would entail.

Finally, in many situations, it is not feasible to simplify the operator's task to the point of requiring of him only simple amplification. In some systems the man is used precisely because he can do more in a tracking loop than amplify. In these circumstances it would be self-defeating to attempt to carry the simplification process too far. This would be true, for example, in the case of handlebar tracking systems which utilize the man, not only as an error detector and analog computer, but as the power drives as well. In such cases, complete redesign of the system would be required if one sought entirely to supplant the human element. In these cases, one must be satisfied with the more modest, yet very appreciable, improvements to be brought about through task simplifications which stop short of the ultimate.

## THE APPLICATION OF THE PRINCIPLE TO THE DESIGN OF MANUAL TRACKING SYSTEMS

The simplest, practical tracking system known which can be made to follow with precision a constant velocity input is represented in Fig. 3(a).[19] In this figure the circles containing crosses represent mechanical or electrical differentials which add algebraically. The system is shown to consist of two cascaded integrators with feed-forward loops around both. Path *c* represents the position component, *b* the velocity component and *a* the acceleration component.

The transfer properties of the part of the system enclosed within the dashed line are expressed in the following equation:

$$\ddot{\theta}_0 = a\theta_i + b\dot{\theta}_i + c\ddot{\theta}_i. \tag{2}$$

This is the "open loop" equation for the system.

Figs. 3(b) and 3(c) represent alternative ways of achieving the same input-output relationships obtaining in 3(a). In both of these figures the process of differentiation is symbolized by a square box containing the ratio *d/dt*. In 3(b), the output of the first integrator is the rate component, while position is obtained by differentiating this rate. In 3(c), a double differentiation of the double integration provides the component of position, while rate is obtained by differentiating only once the output of the two cascaded integrators. Other ways of structuring the block diagram will be apparent, but these will suffice for the purposes of this paper.

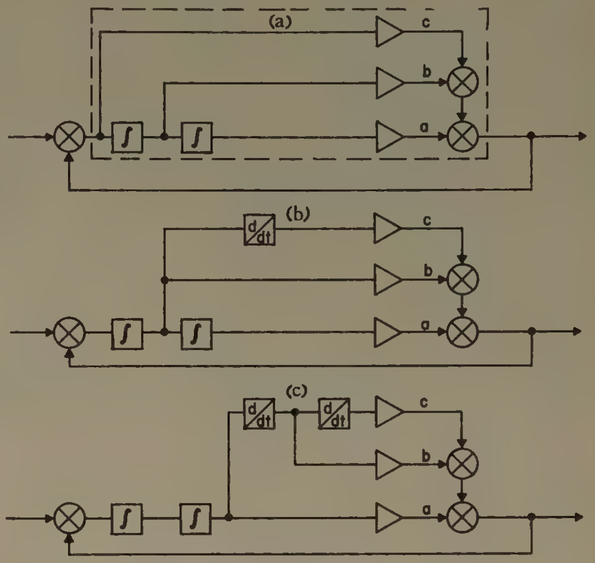

Fig. 3—Three equivalent follow-up systems.

To achieve stability with any one of the three equivalent devices shown above, care must be exercised in properly adjusting the gains of the three pathways. A slight error in setting, if it were in the right direction, would cause the tracking device to become prone to oscillation, and the total removal of the position and velocity pathways would result in pronounced instability.

On the other hand, the removal of the integrators would result in a lag error. If only one integrator was removed, a constant lag error would result, which would be proportional in amplitude to the input velocity. If both integrators were removed, the tracking device would exhibit a lag error which would change in amplitude at a constant rate proportional to input velocity. Obviously, none of these conditions is tolerable in a tracking device.

The transfer properties of the tracking system described above are general, in the sense that they do not specify the precise nature of the mechanisms accomplishing the various functions. Thus, the integrations and feed-forwards required may be performed mechanically, electronically, or even through human behavior. Furthermore, there is nothing to prevent certain of the functions being carried out (say) mechanically, while the remainder are supplied by the behavior of the man.

Such a situation is diagrammed in Fig. 4 (next page). The block diagram represents the human operator as responding to displayed error through the movement of a

[19] Actually, the position pathway is not required for stability if there is no time lag in the system. It can be shown practically, however, that the position component is required for stability if there is a time delay in the system of the order of the human reaction time. Since the argument which will be made requires the transfer properties of the tracking system to be sufficiently general to permit the human to be a part of the tracking loop, the position component must be included. All statements concerning stability are to be read with this consideration in mind.

damped joystick. The figure shows the complete system as consisting of three basic parts: the man, the control, and the mechanism. In the diagram, the damped joystick control is shown as acting as a single integrator in accordance with the earlier discussion. The box in the diagram labeled "mechanism" is represented as performing no function other than amplification.

If it is assumed that the input-output relationship of the man-operated system is a close statistical approximation of that represented in Fig. 3, and if the control element and mechanism element together provide only the function of one integration, it follows that the functions of the second integration and the two feed-forward loops must be supplied by the man. Consequently, in Fig. 4 the man is shown as acting analogously to a differentiator, an amplifier, an integrator, and two algebraic adders, all in combination. The square box labeled "T" is included in the figure as a representation of the human reaction time.

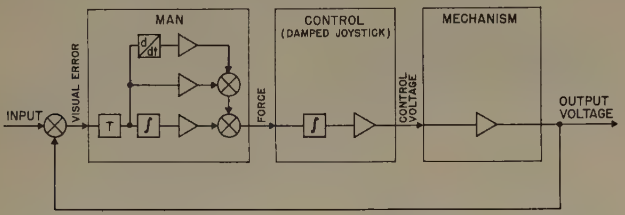

Fig. 4—Tracking system with a damped joystick control and no aiding.

From what has gone before, it would be predicted that the precision of the tracking system would be enhanced if the operator were relieved of the necessity of acting in such a complex fashion. Furthermore, it has been hypothesized that the tracking would be improved most if the man were required to act only as a simple amplifier.

One might accomplish this, leaving the control unchanged, by introducing circuitry into the mechanism which would carry out the required integrations, differentiations and feed-forwards. If this were done, it would be expected that the operator would adjust rapidly to the changed requirements by simplifying his mode of action to a level analogous to simple amplification. All this is tantamount to interchanging the functions of the man and the mechanism as represented in the diagram. In Fig. 5 this interchange has been accomplished.

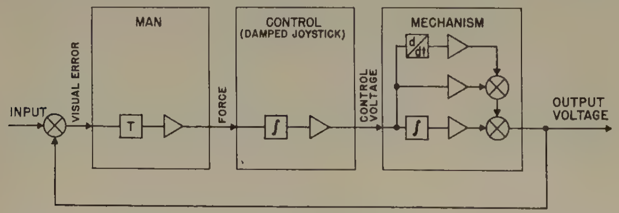

Fig. 5—Tracking system with a damped joystick control and perfect aiding.

## *Aided Tracking*

*Aiding With Different Types of Controls:* Though no direct test of this system design is known ever to have been made, it is interesting to note that an arrangement otherwise identical to that shown in Fig. 5, with the exception that the derivative term is not included, has been used for many years in gun fire control devices under the name of "rate aiding." Much experimental and pragmatic evidence exists to indicate that aiding of this type improves tracking considerably. Tests will be run in the future to check the additional improvement predicted to occur when the derivative term is added to the aiding circuitry.

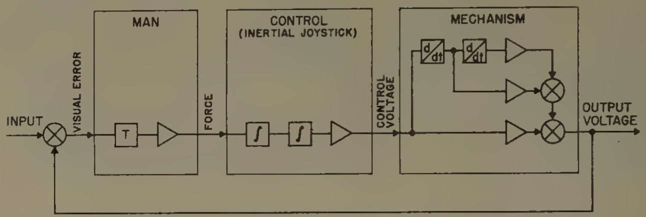

Fig. 6—Tracking system with an inertial joystick and perfect aiding.

At least in theory, it is quite possible to restructure the tracking system for the use of controls other than a damped joystick and still permit the human operator to perform as a simple amplifier. However, to do this, it is necessary to alter the circuitry within the mechanism each time the control is changed in such a fashion as to hold constant the over-all transfer function of both elements acting in combination. Thus, in Fig. 6 may be seen the block diagram of the tracking system arranged for an undamped, high inertia joystick, while Fig. 7 displays the system designed with a pressure joystick as the operator's control.

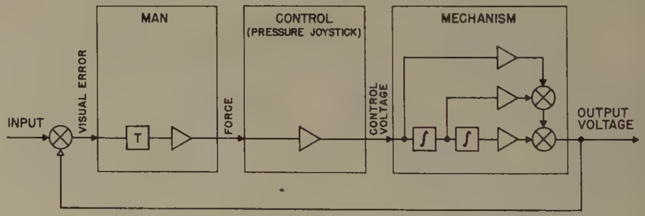

Fig. 7—Tracking system with a pressure joystick and perfect aiding.

It is shown in Fig. 6 that the two integrations are supplied by the action of force on the high inertia control, whereas the mechanism is represented as supplying stabilization through two feed-forward loops supplying position and velocity components to the final output. "Perfect" aiding in this case is obtained through cascading properly two differentiating circuits and a simple amplifier.

Quite different from this is the case in Fig. 7 wherein the tracking control is a pressure joystick. With such a system, the action of force upon the control introduces no integrations, with the result that integrators must be inserted, along with feed-forward loops, within the mechanism. Thus, it should be clear that the circuit requirements for "perfect" aiding vary with the nature of the manual control in use, and that discussions of aided tracking become fully meaningful only when the nature of the control is specified.

Though, reasoning mathematically, there is nothing to permit a choice among the systems shown in Figs. 5, 6, and 7, since they are all equivalent, it is to be expected that some differences will emerge under test. Such differences might be expected to arise from the different kinesthetic patterns set up by the application of force to the three different controls, though at present it is not possible to guess which arrangement would be superior. The reasoning underlying the basic principle enunciated earlier in this report, would lead only to the assertion that all three of the systems would be more precise than any other arrangement which required more of the man than simple amplification.

*The Aiding Required To Track Maneuvering Targets:* Up to now, the discussion has involved manually-operated tracking systems designed to follow constant velocity courses. One is naturally led to wonder what recommendations can be made concerning the design of control systems intended to be used against targets maneuvering realistically. Such target courses contain important amounts of acceleration and rate of change of acceleration and perhaps even higher terms. Certainly, the tracking systems outlined above would have to be modified to handle adequately such inputs. However, it is believed that the reasoning remains the same regardless of the nature of the input. In order to make the system, previously discussed, adequate for tracking courses containing higher derivatives, it is thought necessary to modify them only to the extent of inserting additional integrators with feed-forward loops around them and properly adjusting the gains.

Though no rule is available to indicate precisely how many integrators, with associated feed-forward loops, should be employed for courses of different characteristics, it is thought that little or no improvement would result from the addition of more than four or five. Searle[20] found a definite improvement in system performance when two integrations rather than one were incorporated in an aided tracking circuit. Since he employed a damped joystick, the total number of integrations taking place between the hand and the system output were three in the case of the best arrangement, and two for the other. Unfortunately, neither he nor anyone else has reported systematic tests of aiding arrangements incorporating more than three integrations.

The control designer's task of choosing the proper number of integrations, with associated feed-forward loops, is made less critical by the fact that if more integrations are provided than are needed at any moment, the superfluous integrations do no harm as long as stability and transient problems have been handled adequately. The unnecessary integrating devices merely fail to contribute significantly to the output under these circumstances and, thus, at worst, only a waste of circuitry is involved. Because of this, it would seem prudent to build aided tracking systems which are intended to handle a variety of inputs with a sufficient number of integrating circuits to provide for the more complex target courses expected. By this means, maximum tracking precision will be assured at all times regardless of the complexity of the tracking task.

*Aiding Ratios:* It has been pointed out that the purpose of aided tracking is to remove from the operator the burden of integration, differentiation, feed-forward and analog addition and multiplication and to permit him to operate as a simple amplifier. To approach this ideal as closely as possible, it is necessary, not only to insert the proper components into the mechanism, but also to adjust the various gains correctly.

It is known that the optimum relationship between the gains of the various feed-forward loops varies with the time delays in the system and with the number of components being combined. Because of this, tests of the optimum "time constant" (position sensitivity divided by rate sensitivity) give values which vary from 0.25 to 5.0 seconds.[6] It appears, however, that for continuous tracking tasks where the loop is tight and where the display is such as to permit fine resolution, the optimum time constant lies between 0.3 and 0.5 sec.

As to time constants for discontinuous tracking tasks, Mechler, Russell, and Preston[21] developed an equation for the optimum aiding ratio to be used with PPI presentations where the target appears intermittently. They concluded that the optimum time constant in such use always equalled the number of seconds between "paints" on the radar screen. They also pointed out that their result was consistent with a time constant of about one half-second for continuous tracking if the man is assumed to respond intermittently at intervals of 0.5 sec.

Assuming that the addition of an acceleration component to position and rate would improve system performance for continuous racking tasks, Searle[20] undertook a series of tests of aided tracking. Accepting the assumption of intermittent sampling by the operator at a frequency of two per second, and carrying over the reasoning of Mechler, Russell, and Preston to include acceleration, Searle predicted that the optimum ratios of component sensitivities would be 1 to 4 to 8 for position, rate, and acceleration, respectively. This prediction was confirmed in two of three experiments which he ran. In a third test an aiding ratio of 1 to 2 to 8 proved to be slightly superior to the predicted optimum. This single discrepancy is not at all surprising in view of the multiplicity of factors involved in determining optimum time constants of this variety.

But though an interplay of many processes determines optimum aiding ratios, it is possible to give a very general statement of what is accomplished when the sensitivity values of the various components are proportioned correctly. It appears that the proper aiding constants for any manually-operated control system are such that the correction of the position error simultaneously reduces to zero any concomitant errors in rate, acceleration, or the higher derivatives. When such a condition prevails, continuously sustained actions are made unnecessary and the man can track accurately by acting as a simple amplifier.

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[20] L. V. Searle, "Psychological Studies of Tracking Behavior. Part IV: The Intermittency Hypothesis as a Basis for Predicting Optimum Aided-Tracking Time Constants," NRL Rep. No. 3872; 1951.

[21] E. A. Mechler, J. B. Russell, and M. G. Preston, "The basis for the optimum aided-tracking time constant," *Jour. Frank. Inst.*, vol. 248, pp. 327–334; 1949.

It is true, of course, that since human reaction time varies from person-to-person and from moment-to-moment, the best aiding ratios are correct only on the average. This means that the operator will be free to act as an amplifier only in a statistical or average sense. To the extent that the man samples irregularly rather than periodically, it will be necessary for him to add to his basic process of amplification—at one time, integration, at another, differentiation. However, it is assumed that, on the average, the transfer function of the adept tracker will approximate that of a simple amplifier if the sensitivities of the various feed-forward loops are adjusted properly.

## THE APPLICATION OF THE PRINCIPLE TO THE DESIGN OF SPECIAL CONTROL SYSTEM DISPLAYS

### *Unburdening and Quickening*

An "anthropocentric" analysis of the manner in which aiding enhances system performance uncovers two processes which act simultaneously but in quite different ways to simplify the human operator's task and to better system operation. One of these has the effect of relieving the man of the necessity of applying force continuously or in some time-sequenced pattern. In the systems discussed, relief has been provided by inserting integrators in the mechanical portions of the system. This process of easing the human's task by reducing the required effort may be termed "unburdening," since it has this effect on the man. Because in some practical instances unburdening is accomplished by regenerative computers considerably more complex than simple integrators, the term appears to be generic and to apply in many situations not hitherto discussed.

A second process, of equal importance, may also be distinguished as contributing to the enhancement of system performance brought about through aiding. This process may be termed "quickening," since one of its effects is to provide the operator with immediate knowledge of the results of his own actions. In aiding, quickening is accomplished by feed-forward loops which add position, rate and other necessary higher components to the output of the integrators which are performing the unburdening operation. Since the system output is continuously fed back and displayed to the operator, he is made instantaneously aware of the early effects of his own actions if quickening is adequate.

In the tracking systems discussed up to now the two processes complement one another, with unburdening making it unnecessary for the operator to supply integrations, and with quickening, relieving the human of the necessity of differentiating. Both meliorate system precision; the former process by reducing human effort and removing lag errors, the latter process by providing stability.

In all of the systems met with so far, unburdening and quickening have a direct effect on the system output, as well as a secondary, indirect effect resulting from the operator's responses to these changes. Though it would seem that the very nature of unburdening was such that it could not be achieved without direct modification of the output, this is not true of quickening. In certain circumstances the latter can be accomplished through altering the nature of the information fed back and displayed to the man, without changing in any direct fashion the output of the system. This is an extremely important fact, since it means the benefits of quickening can be achieved even in those systems where, for one reason or another, the output is inaccessible to direct manipulation. Thus, in such man-machine control systems as those of ships and airplanes, where the outputs are determined in large part by immutable hydrodynamic or aerodynamic force relationships, enhanced stability and precision are still attainable through the quickening of the information displayed to the human operator. This corresponds closely to the use of certain types of equalization networks to stabilize fully automatic systems in similar situations.

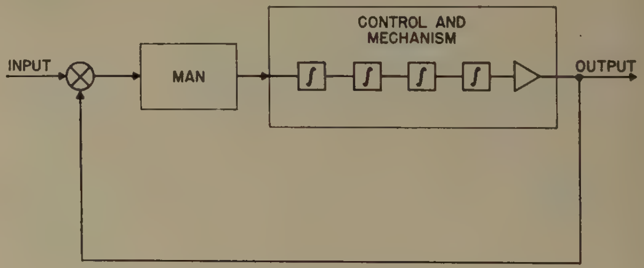

Fig. 8—A control system requiring quickening.

### *A Quickened Display*

An example of a case requiring display quickening is provided by a control system block diagrammed in Fig. 8. This device is intended to operate on a course input which consists only of step-function position changes, so spaced that the full correction of any one step may be achieved before the next requires action. The time constants of the four integrators are long, and this, coupled with the fact that the integrators shift the phase of the input through 360 degrees, causes the system to be quite unstable.

The quickening of this device presents an intriguing problem since the obvious solution diagrammed in Fig. 9 (facing page) is ruled out by circumstances which prevent making changes which affect directly the output of the control system. The problem may be solved, how-

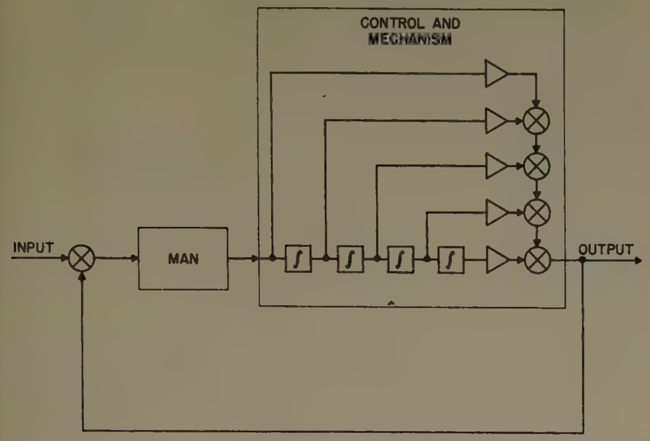

Fig. 9—The control system with quickening taking effect on output.

ever, by picking off the components of position, rate, acceleration and the first derivative of acceleration, amplifying them properly and adding them algebraically in the feedback loop going to the display. Fig. 10 shows this arrangement. The display may take the form of a double-pointer dial, with one pointer responding to ordered input and with the other being controlled by the quickened feedback. With this arrangement, the man has only to operate his control so that the follow-up pointer matches the input pointer at all times. Tests run with such a device have indicated that instability may be completely eliminated by this means of quickening.

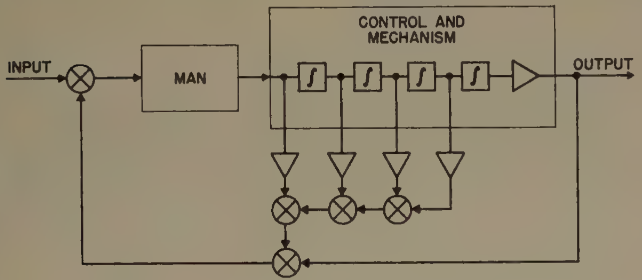

Fig. 10—The control system with quickening taking effect on display.

Two other examples of quickened displays similar to this are provided in aircraft instrument developments. The first, and probably the best known, example of display quickening is furnished by an instrument known as "The Sperry Zero Reader."[22,23] The other example is the "Instrument Approach System Steering Computer," described by Anderson and Fritze.[24] Both of these developments incorporate circuits which effect a partial tightening of the loop around the pilot by giving him more immediate knowledge of the results of his responses.

### *Quickening a Filtered Display*

The insertion of a filter into a control loop often results in system instability. A tracking system degraded in this fashion is pictured in Fig. 11. In this diagram, the filter is shown as taking effect on error which, in this case, is the algebraic sum of the input and the output.

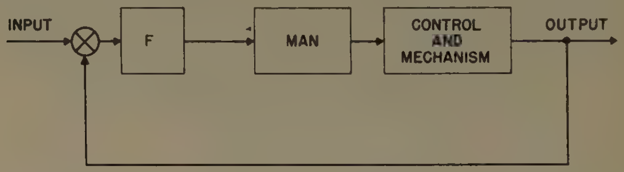

Fig. 11—A control system with filter in loop.

Tests of such a tracking system show that, with moderate or long time constants of the filter, the output tends to oscillate. This is the result of the fact that the operator perpetually over- and under-shoots in his corrections since the filter distorts and delays information about the effects of his own behavior. Quickening is required to overcome this lag between what the man does and what he sees himself do.

Such quickening is provided by the insertion of two special high-pass filters in the manner shown in Fig. 12. Now, the higher frequencies in the operator's output which were absorbed by the low-pass filter of the system, as shown in Fig. 11, reach the display. The complementary IF filter and the "antibias" network act together to quicken the human's high frequency correction motions without introducing a bias such as would occur if the IF filter were employed in isolation. The conjoint use of these two types of filter is termed "treatment."

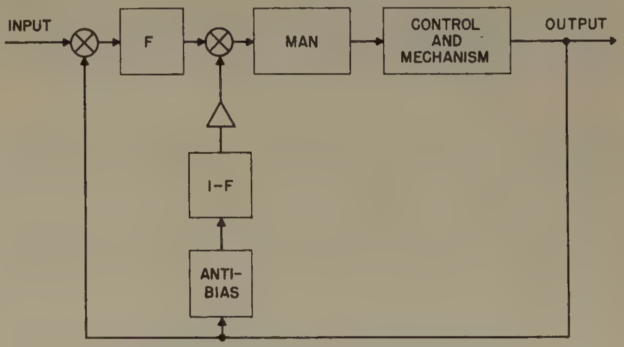

Fig. 12—Treatment of a filtered display.

A simulator was set up at NRL to act as an analog of this system. Human operators tracked a sinusoidal course with the device and the system output was recorded. Three conditions were compared. In one-third of the trials the operators tracked with no filters and no treatment circuits in the system (Condition 1). Another third of the trials was run with the filter in, but with no treatment (Condition 2). This condition is represented in Fig. 11. The remainder of the trials were run with the filter in and with treatment also incorporated in the system as in Fig. 12 (Condition 3).

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[22] S. Kellogg and C. F. Fragola, "The Sperry zero reader," *Aeronaut. Eng. Rev.*, vol. 8, pp. 22–31; 1949.

[23] F. G. Nesbitt, "The Sperry zero reader," *Sperryscope*," vol. 11, pp. 2–6; 1949.

[24] W. G. Anderson and E. H. Fritze, "Instrument approach system steering computer," PROC. I.R.E., vol. 41, pp. 219–228; February, 1953.

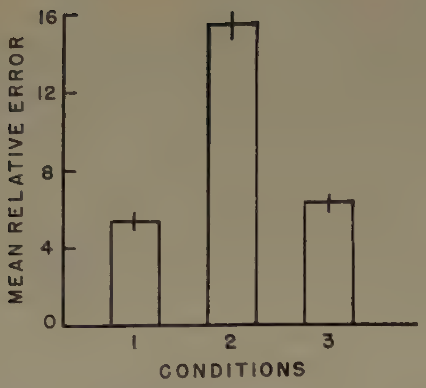

Fig. 13—The effect of filtering and treatment upon tracking error.

The results of this experiment are shown in Fig. 13. It is clear that the quickening produced by treatment was efficacious in reducing the tracking error almost to the level obtaining in Condition 1. Thus, the degrading effects of the original filter are almost completely removed by the treatment networks.

An analysis of the control system described earlier, and diagrammed in Figs. 8, 9 and 10, indicates that had the input to the system been anything other than a series of step function position changes, an antibias network similar to that employed above would have been required if the quickening were performed as in Fig. 10. In fact, it is probably true that most efforts to quicken a display without affecting the system output directly will result in a system bias, unless some form of anti-bias network is included in the quickening circuitry. At present, the design of these anti-bias circuits is a relatively undeveloped, but highly promising, field.

# Dielectric Potentiometers*

GEORGE E. PIHL†, ASSOCIATE, IRE

*Summary*—**The term "dielectric potentiometer" is used to designate a new type of controllable voltage divider employing a lossy liquid dielectric as the impedance medium. With proper design, the dielectric potentiometer may be operated over an extremely wide frequency range with a flat amplitude response and zero phase shift. Unlike conventional wire-wound and film type controls, the new device is readily capable of being perfectly compensated for broadband operation when operated into either resistive or capacitive loading, or a parallel combination of both. Other advantages include infinite resolution, long life, and adaptability to specific nonlinear requirements. Probable advantages such as a low noise figure and the capability of operation at high rotational speeds have yet to be experimentally investigated. Examples of designs for particular applications are given.**

## INTRODUCTION

WHAT APPEARS to be a new form of potentiometer or voltage divider has been discovered. This came about during an investigation of various variable impedance devices suitable for use in amplitude compression systems. The requirements included wide frequency response, large dynamic range, rapid operation, and minimum amplitude distortion. In an effort to avoid the distortion inherent to nonlinear devices commonly used for automatic amplitude control, consideration was given to mechanically-actuated voltage dividers. As a result, a miniature broadband dielectric potentiometer has been developed having a self-contained magnetically-operated rotor. Used in a high-gain, closed-loop system, the device is capable of maintaining a constant output amplitude for input voltage variations over a 35 db range without appreciable amplitude, frequency, or phase distortion for frequencies between 50 cps and 1.0 mc. The response time is of the order of 100 millisec.

Subsequent development has led to designs for other applications where manually-operated precision controls having greater bandwidth capability than conventional wire-wound controls are necessary.

## BASIC PRINCIPLES

The successful operation of a dielectric potentiometer depends upon the simultaneous variation of resistance and capacitance existing between a movable electrode and a system of fixed electrodes all immersed in a lossy liquid dielectric. To understand the operation of such a device, consider first the simple system shown in Fig. 1.

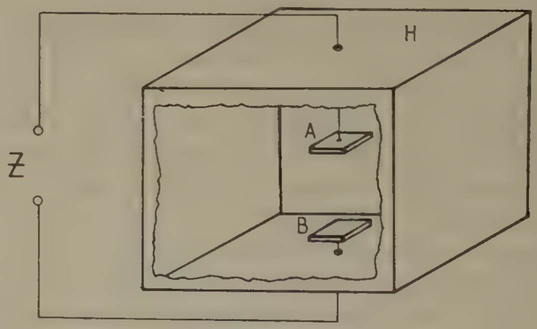

Fig. 1—Two-terminal dielectric device.

In this sketch, *A* and *B* represent metallic electrodes of arbitrary shape having connections brought out of the enclosure *H* through hermetic seals. If the enclosure is filled with a fluid having a particular resistivity $\rho$ and dielectric-constant $\epsilon$, the impedance *Z* observed at the indicated pair of terminals may be expressed as a parallel combination of fixed resistance and fixed capacitance over a wide frequency range. The capacitance is determined from the ratio of charge $Q$ to applied voltage $V$, expressing $Q$ in terms of a surface integral of $E$, the electric field intensity, taken over the surface of one of the electrodes, and is:

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* Original manuscript received by the IRE, June 7, 1954; revised manuscript received, August 18, 1954.

† Technology Instrument Corp., Acton, Mass.

$$C = \frac{Q}{V} = \frac{\oint_S \frac{\epsilon E}{4\pi} ds}{V}. \qquad (1)$$

Similarly the parallel resistance between $A$ and $B$ can be determined from the ratio of applied voltage $V$ to conduction current $I$ expressed as a surface integral.

$$R = \frac{V}{I} = \frac{V}{\oint_S \frac{E}{\rho} ds}. \qquad (2)$$

Providing that the entire field associated with $A$ and $B$ is confined to the region interior to $H$, and therefore $\epsilon$ and $\rho$ in the above equations are constants, then by inspection:

$$RC = \frac{\epsilon\rho}{4\pi}. \qquad (3)$$

This equation indicates that regardless of the size, shape or spacing of electrodes $A$ and $B$, the product of the equivalent parallel resistance and capacitance values is a constant and depends only upon the dielectric fluid employed. This is an exceedingly useful property and makes possible the broadband operation of a dielectric potentiometer.

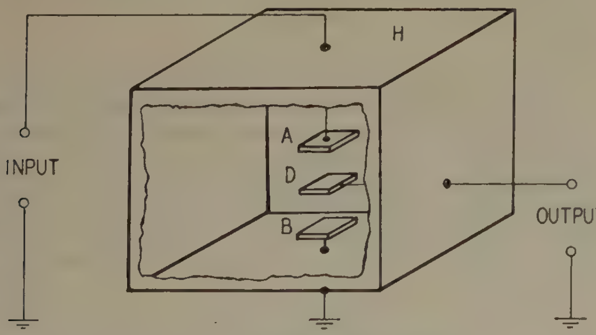

Fig. 2—Basic dielectric potentiometer.

## Frequency Response

The basic elements of a dielectric potentiometer are illustrated in Fig. 2, consisting of a movable electrode $D$ in the vicinity of a pair of fixed electrodes $A$ and $B$, the whole enclosed by a metallic container $H$.

The input and output connections are made to $A$ and $D$ respectively through insulated bushings. Electrode $B$ is connected to the casing $H$ and forms the common ground connection between input and output. The container is filled with a liquid dielectric having considerable loss and, therefore, the output-to-input voltage ratio is determined by both resistive and capacitive coupling. From the foregoing it is apparent that the equivalent circuit of the device is as shown in Fig. 3, where:

$R_1$ = resistance between $D$ and ground
$C_1$ = capacitance between $D$ and ground
$R_2$ = resistance between $A$ and $D$
$C_2$ = capacitance between $A$ and $D$
$R_3$ = resistance between $A$ and ground
$C_3$ = capacitance between $A$ and ground.

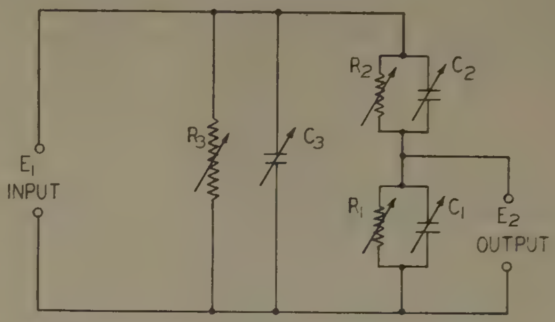

Fig. 3—Equivalent circuit of dielectric potentiometer.

Since it has been shown that the $RC$ product is constant for the $R$ and $C$ values between any pair of electrodes, it follows that the voltage divider is inherently self-compensated and has no frequency or phase distortion within the range of frequencies where steady-state approximations apply.

It should be noted that $R_3$ and $C_3$ are, to some extent, variables with the position of $A$ but influence only the input impedance, not the voltage ratio.

It is to be emphasized that broadband operation depends directly upon the constancy of the $RC$ product which depends upon coincidence of the conduction and displacement current paths. It is for this reason that a grounded metallic housing is used in order to bound the electric field to the region occupied by the liquid dielectric. It is also essential to minimize the solid dielectric used for insulating supports in constructing the device. Such supports should be placed as far as possible in regions of minimum and constant field strength.

## Compensation for Loading

The above discussion has been made under the assumption that no external loading exists due to stray or deliberate terminal capacitance or resistance. In the practical use of the device it is inevitable that some sort of load be present, a vacuum tube grid in the usual case. It is also likely in many applications that stray capacitive coupling will exist between input and output. Both of these conditions can be perfectly compensated by adding parallel resistance or capacitance such as to make the external $RC$ products equal to that inherent to the liquid dielectric. This is illustrated in Fig. 4 (next page) for the case where such capacitances exist. Here $Rm$ and $Ro$ have been added to satisfy the relation:

$$R_0C_0 = R_MC_M = \frac{\epsilon\rho}{4\pi}. \qquad (4)$$

Under this condition the frequency response is preserved although the voltage ratio as a function of electrode displacement is changed. The effects of external loading must be taken into account when designing to a particular function.

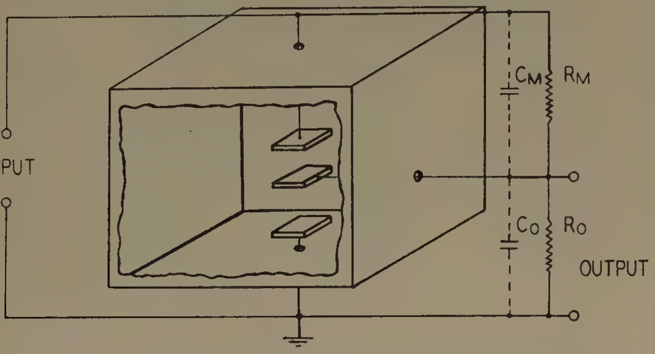

Fig. 4—Compensation for external capacitances.

## PRACTICAL EXAMPLES

A logarithmic potentiometer operating according to the principles outlined above has been designed and constructed for use over a 25 db range of attenuation and for frequencies between 20 cps and 1.0 mc. A sketch showing a cross section is shown as Fig. 5.

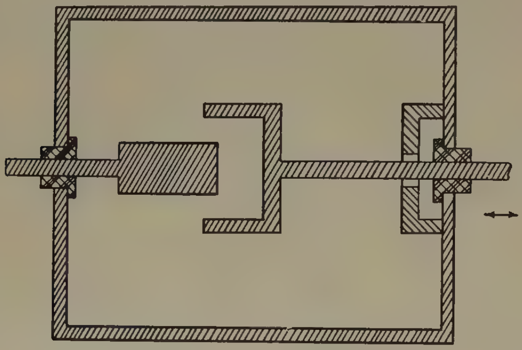

Fig. 5—Logarithmic potentiometer construction.

The entire device has cylindrical symmetry about the horizontal axis, the input electrode being a small solid cylinder supported by a cylindrical rod insulated from the case with a small bushing. The movable output electrode is a hollow cylindrical cup supported by a small diameter shaft passing through an *O*-ring seal and insulated bushing. Note that in this design the left-hand bushing is effectively guarded by the input electrode while the right-hand bushing has a hollow cylindrical guard shield around it. When operated into a cathode-follower load and properly compensated with an external resistance between output and ground, the curve of the log of the voltage ratio versus electrode displacement is linear within 0.25 db.

For designs requiring greater conformity to logarithmic operation, advantage might be taken of a geometrical configuration of electrodes which yields a true logarithmic field distribution, such as a system of coaxial cylinders.

Another type of dielectric potentiometer, designed for use in the automatic attenuating system mentioned in the INTRODUCTION is illustrated in cross section as Fig. 6.

In this device, the output-to-input voltage ratio depends upon the physical position of the vane *K* attached to the shaft *S* which is supported by jeweled bearings *F-F*. Over the range of operation from minimum to maximum output, vane *K* is closely coupled to the output electrode *A* through the dielectric fluid, thus obviating the need for a sliding contact. In the minimum position the vane is closely coupled to the grounded electrode *D* while in the maximum position the coupling is to *B*. Positioning of the shaft is accomplished by adjustment of the currents carried by the two coils which operate on the small permanent-magnet rotor carried on the upper end of the shaft. Notice that this design has the advantage that the enclosure can be permanently sealed, there being no rotating or sliding seals to contend with.

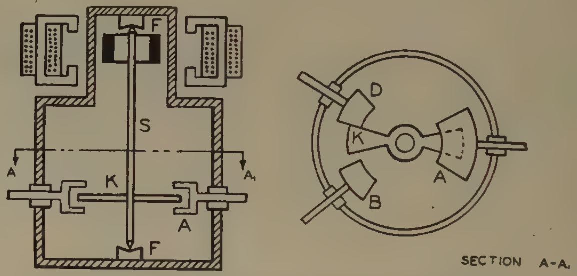

Fig. 6—Self-actuated dielectric potentiometer.

## DIELECTRIC FLUIDS

The electrical, mechanical, and chemical characteristics of fluids suitable for dielectric potentiometers must satisfy a number of requirements. Foremost, the values of $\epsilon$ and $\rho$ (together with electrode dimensions) must be such as to yield suitable resistance and capacitance values consistent with the desired input and output impedances over the frequency range. Preferably, of course, $\epsilon$ and $\rho$ would be independent of temperature and frequency. The liquid should have a low freezing point and high boiling point and be noncorrosive.

The liquids which thus far have been found most suitable are the alcohols. Methyl alcohol has a resistivity of of $0.14 \times 10^6$ ohm-cm at room temperature and a dielectric constant of 31.2 yielding an *RC* product of $0.39 \times 10^{-6}$ ohm-farad. This value is quite suitable for equalization purposes requiring approximately 80 $K\Omega$ to compensate for a load capacitance of 5 $\mu\mu$f. Other alcohols such as ethyl and isopropyl have also been used with excellent results.

The freezing and boiling points for these alcohols are considered adequate for most applications.

Some tests have been made of the effects of corrosion and electrolysis with satisfactory results having been obtained using aluminum construction with nylon insulators for frequencies above 10 cps. If greater strength is required, stainless steel has been found suitable. Below 10 cps special materials are necessary.

One of the serious objections to the use of the alcohols as dielectrics in some applications is the rather violent dependence of $\rho$ upon temperature, which therefore produces an input impedance which is variable with temperature. It should be understood, however, that a change of resistivity affects the frequency response only to the extent that the potentiometer is compensated with external resistance and capacitance. Since the external $RC$ product must match the internal $RC$ product of the fluid for perfect compensation, the compensation will be in error as $\rho$ varies.

### Input Impedance

From an examination of Fig. 3 it is apparent that the input impedance of a dielectric potentiometer at any setting may be represented by the parallel combination of a resistance $R_t$ and a capacitance $C_t$. The input impedance will therefore vary with frequency according to the following relations:

$$|Z_{IN}| = \frac{R_t}{\sqrt{1 + (R\omega C)^2}} \tag{5}$$

$$\theta_{IN} = -\tan^{-1}(R\omega C) \tag{6}$$

where $RC$ is the value computed from (3).

It is evident from the above that the low-frequency input impedance is $R_t$ and that the magnitude of the impedance decreases with frequency. For instance, using the $RC$ value previously given for methyl alcohol, the input impedance will be reduced by a factor of 2.4 at 1.0 mc.

For this reason a low impedance driving source must ordinarily be used.

By the appropriate selection of electrode dimensions and type of dielectric, potentiometers have been constructed with $R_t$ values ranging from a few hundred ohms to several megohms.

### Conclusion

From the foregoing discussion, it would appear that the dielectric potentiometer should, after sufficient development, satisfy the definite need for a low-cost, precision, broadband control, having infinite resolution, long-life, a variety of possible control functions, and the capability of operating at high speed. Further development should be concerned with a study of compatible construction materials and dielectrics, a thorough study of available dielectric fluids and their properties, and an investigation of methods for providing reliable rotary hermetic seals.

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# Large-Signal Behavior of Junction Transistors*

J. J. EBERS†, ASSOCIATE, IRE AND J. L. MOLL†, ASSOCIATE, IRE

*Summary*—**In the consideration of the junction transistor as a switch there are three characteristics of primary interest, the open mpedance, the closed impedance, and the switching-time. A generalized two-terminal-pair theory of junction transistors is presented which is applicable, on a dc basis, in all regions of operation. Using this theory, the open and closed impedances of the transistor switch are expressible in terms of easily measurable transistor parameters. For the ideal transistor these parameters are the saturation currents of the emitter and collector junctions and the normal and inverted lphas.**

**The transition of the transistor switch from open to closed, or vice versa, is discussed, including the effects of minority carrier storage. This transition can be expressed in analytic form in terms of the lphas and the normal and inverted alpha cut-off frequencies.**

### Introduction

OF ALL THE electronic devices which may be used in large-signal or nonlinear applications, notable among which is switching, the junction transistor seems to lend itself most easily to analysis. Whether the transistor, used as a switch, is in the "on" condition, the "off" condition, or the transition region between "off" and "on," the behavior can be calculated with considerable accuracy. In principle only five parameters are necessary to completely characterize an ideal transistor. These five parameters, on the other hand, are related to the structure of the transistor in such a way as to allow a high degree of designability. In addition, junction transistors can perform functions that cannot be done by any other known electronic device. An example is the junction transistor used as a nonregenerative switch, that is, a switch which can be maintained in an altered condition only by the continued application of sufficient control signal or stimulus. The transistor used in this application can have many megohms impedance in the "off" condition and less than an ohm in the "on" condition. The actual dc voltage across the transistor switch in the "on" condition can be as low as a few millivolts. Nonregenerative transistor switches can be switched from "off" to "on," or vice versa, in times as low as a tenth of a microsecond with presently available transistors. The ratio of power supplied to a load to the power necessary to activate the

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* Original manuscript received by the IRE, July 19, 1954.

† Bell Telephone Labs. Inc., Murray Hill, N. J.

switch can be several thousand. In the case of regenerative switches, that is, switches which can be switched from "off" to "on," or vice versa, by the application of a trigger, the ratio of controlled power to controlling power may be factors of ten higher than for nonregenerative switches.

The object of this paper is to present a theory which completely relates the large signal behavior of the junction transistor to the familiar small signal transistor parameters. The theory presented is applicable to all large-signal applications, switching being an extreme case since, in general, all three regions of operation are traversed. These regions have been defined by Anderson[1] as follows:

Region I: collector current cutoff or collector voltage saturation,
Region II: active region, and
Region III: collector current saturation, or collector voltage cutoff.

In the analysis to follow, the dc behavior will again be divided into these three regions. The descriptions of the regions of operation as given by Anderson can be applied to junction transistors as well as to point contact transistors. Collector characteristics for a typical junction transistor are shown in Fig. 1. The boundaries of Regions I, II, and III are considered in greater detail in a later section. However, Fig. 1 shows that these three regions can be identified approximately by the following conditions (for *n-p-n* or *p-n-p* junction transistors).

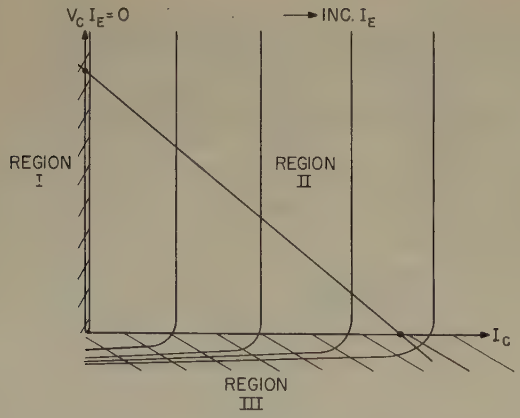

Fig. 1—Transistor collector characteristics, common-base connection.

Region I: emitter junction reverse biased and collector junction reverse biased,
Region II: emitter junction forward biased and collector junction reverse biased,
Region III: emitter junction forward biased and collector junction forward biased.

In addition to a determination of the dc behavior, the analysis will also be concerned with the transient behavior in switching from one region to another. The effects on switching-time of alpha-frequency cutoff, collector capacitance, and minority carrier storage, will be considered.

## THE NONLINEAR EQUATIONS

In the analysis of circuits which contain one or more nonlinear elements, it is often possible to obtain a first order solution by studying the characteristics of the nonlinear elements and determining regions within which the characteristics can be assumed to be linear. Such a broken-line analysis has been carried through on point-contact transistors.[1]

A similar approach is often used when the circuits contain point-contact, semi-conducting diodes. In this case it is assumed that the diode has a constant low resistance in the forward direction, and a constant high resistance in the reverse direction. In some cases, however, the nonlinearity is best described by analytic, nonlinear relations between terminal currents and voltages. For example, current and voltage of *p-n* junction diodes are related by the equation

$$I = I_s(e^{qV/kT} - 1) \tag{1}$$

where $kT/q = 0.026$ volts at room temperature (25 degrees C.) and $I_s$ is the reverse saturation current. While *p-n* junction diodes have been made which agree with (1) over limited ranges of voltage, the relation (1) does not exactly represent the diode behavior in practice.

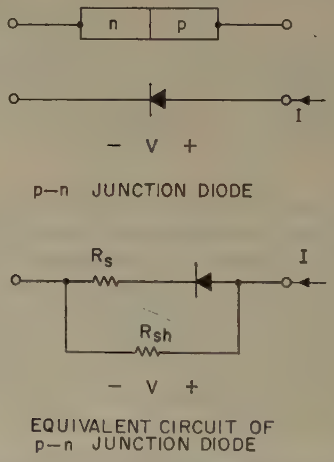

Fig. 2—Junction diode representation.

However, deviations from the theoretical nonlinear behavior can be very nearly described over a wide range of variables by means of the addition of linear elements in parallel or in series with an ideal[2] *p-n* diode. A small parallel conductance accounts for the finite slope of the reverse characteristic, and a small series resistance accounts for the voltage drop in the body of the semiconductor. Thus, the complete dc behavior is given by the circuit of Fig. 2. For a typical germanium *p-n* junction diode $R_s$ is one to ten ohms and $R_{sh}$ is one to fifty megohms. This more complicated representation accurately represents the behavior of the junction diode.

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[1] A. E. Anderson, "Transistors in switching circuits," Proc. I.R.E., vol. 40, pp. 1541–1548; November, 1952.

[2] By an ideal diode is meant one which has terminal relations described by (1).

Analytical expressions can also be obtained for *p-n* junction transistors from which the gross nonlinear behavior can be determined. For a generalized junction transistor, such as shown in Fig. 3, these equations are

$$I_E = a_{11}(e^{q\Phi_E/kT} - 1) + a_{12}(e^{q\Phi_C/kT} - 1) \qquad (2)$$

and

$$I_C = a_{21}(e^{q\Phi_E/kT} - 1) + a_{22}(e^{q\Phi_C/kT} - 1). \qquad (3)$$

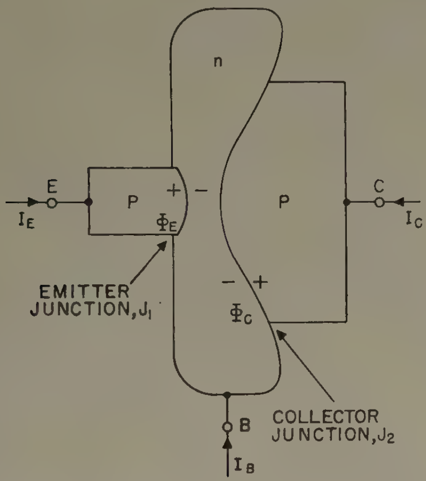

Fig. 3—Junction transistor, generalized geometry.

These equations are derived in the Appendix for the case of a transistor in which practically no restrictions are placed upon the geometry. The quantities $\Phi_E$ and $\Phi_C$ are the junction voltages. The positive sense of these voltages is a voltage drop from *p* material to *n* material. (For example, see Fig. 3.) The most important assumptions are as follows:

1. That the resistivities of the semi-conductor regions are low.
2. That the injected current densities are low. (Assumptions 1 and 2 insure that there are no voltage drops within the semi-conductor other than those across the junctions, and that the emitter efficiency is not a function of emitter current.)
3. That space-charge layer widening effects[3] can be neglected.
4. That the emitter and collector junctions, separately, have current-voltage relations of the form given in (1). (In a large-signal analysis departures from the above assumptions are assumed to be negligible in comparison to the major nonlinearities.)

It is seen that the equations are similar to those of ordinary coupled circuits. Under all conditions of bias on the junctions the current of one junction is due to two components—one due to the voltage across that junction and another due to the voltage across the other junction. In addition it is shown in the Appendix that even for the most general geometry[4]

$$a_{12} = a_{21}. \qquad (4)$$

Eq. (4) is reminiscent of the condition for bilateralism in linear two-terminal-pair networks. The transistor is obviously not bilateral, however, and the nonbilateralism is taken care of by the form of the voltage functions in (2) and (3).

The problem is to show that the coefficients $a_{11}$, $a_{12}$, $a_{21}$ and $a_{22}$ (which might be called the four-pole $a$'s), which appear in (2) and (3), can be determined from the following transistor parameters:

$I_{EO}$ = saturation current of emitter junction with zero collector current,
$I_{CO}$ = saturation current of collector junction with zero emitter current,
$\alpha_N$ = transistor current gain with the emitter[5] functioning as an emitter and the collector functioning as a collector (normal alpha), and
$\alpha_I$ = transistor current gain with the collector functioning as an emitter and the emitter functioning as a collector (inverted alpha).

For the positive senses of currents shown in Fig. 3, $I_{EO}$ and $I_{CO}$ are positive quantities for *n-p-n* transistors and negative quantities for *p-n-p* transistors. This distinction is made in order that the derived equations be applicable to either type. The alphas in this paper are taken to mean the fraction of the emitter current which is collected and, hence, might be called dc alphas. Only three of the above quantities are independent and in fact it will be shown that $\alpha_N I_{EO} = \alpha_I I_{CO}$.

The four quantities $\alpha_N$, $\alpha_I$, $I_{EO}$, and $I_{CO}$ are most easily related to the $a$'s if it is assumed in (2) and (3) that the transistor is operating in the linear or active region of its characteristics with a reverse bias across the junction functioning as the collector. Eqs. (2) and (3) become, for reverse collector bias,

$$I_E = a_{11}(e^{q\Phi_E/kT} - 1) - a_{12} \qquad (5)$$

and

$$I_C = a_{21}(e^{q\Phi_E/kT} - 1) - a_{22}. \qquad (6)$$

Solving (5) for

$$(e^{q\Phi_E/kT} - 1),$$

and substituting this value in (6),

$$I_C = \frac{a_{21}}{a_{11}} I_E + \left(\frac{a_{12}a_{21}}{a_{11}} - a_{22}\right). \qquad (7)$$

---

[3] J. M. Early, "Effects of space-charge layer widening in junction transistors," Proc. I.R.E., vol. 40, pp. 1401–1406; November, 1952.

[4] This relation has previously been obtained by a different method. See W. Shockley, M. Sparks, and G. K. Teal, "The *p-n* junction transistors," *Phys. Rev.*, vol. 83, pp. 151–162; July, 1951.

[5] It is assumed that when the transistor is fabricated, one rectifying contact is marked emitter and the other is marked collector.

This equation shows a linear relation between emitter and collector current. It can be written as

$$I_C = -\alpha_N I_E + I_{CO}, \tag{8}$$

where $\alpha_N$ and $I_{CO}$ have the definitions previously given. It is interesting to note that, except for second order effects, the alpha of the transistor is theoretically a constant even for reverse values of emitter current. This has been found to be true for small values of emitter current if both junctions have rectification characteristics which saturate. Transfer characteristics for an *n-p-n* transistor are shown in Fig. 4. This figure illustrates the constancy of alpha as a function of emitter current for low values of current.

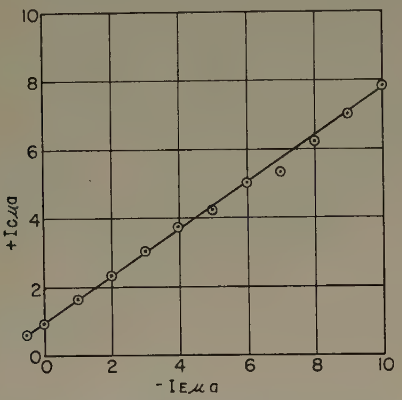

Fig. 4—Current transfer characteristics of a junction transistor for small emitter currents.

If the emitter is reverse biased and the collector is used as the emitter, the following equation is obtained

$$I_E = \frac{a_{12}}{a_{22}} I_C + \left(\frac{a_{12}a_{21}}{a_{22}} - a_{11}\right). \tag{9}$$

For the inverted transistor an equation analogous to (8) can be written

$$I_E = -\alpha_I I_C + I_{EO}. \tag{10}$$

Using (7) to (10), and comparing coefficients, the $a$'s can be evaluated and are given by

$$a_{11} = -\frac{I_{EO}}{1 - \alpha_N \alpha_I} \tag{11}$$

$$a_{22} = -\frac{I_{CO}}{1 - \alpha_N \alpha_I} \tag{12}$$

$$a_{12} = +\frac{\alpha_I I_{CO}}{1 - \alpha_N \alpha_I} \tag{13}$$

$$a_{21} = +\frac{\alpha_N I_{EO}}{1 - \alpha_N \alpha_I}. \tag{14}$$

Since $a_{12} = a_{21}$,[6]

$$\alpha_I I_{CO} = \alpha_N I_{EO}. \tag{15}$$

Substituting the values of the $a$'s in (2) and (3)

$$I_E = -\frac{I_{EO}}{1 - \alpha_N \alpha_I}(e^{q\Phi_E/kT} - 1) + \frac{\alpha_I I_{CO}}{1 - \alpha_N \alpha_I}(e^{q\Phi_C/kT} - 1) \tag{16}$$

and

$$I_C = +\frac{\alpha_N I_{EO}}{1 - \alpha_N \alpha_I}(e^{q\Phi_E/kT} - 1) - \frac{I_{CO}}{1 - \alpha_N \alpha_I}(e^{q\Phi_C/kT} - 1). \tag{17}$$

If these equations are solved for the exponential factors in terms of $I_E$ and $I_C$

$$-I_{EO}(e^{q\Phi_E/kT} - 1) = I_E + \alpha_I I_C \tag{18}$$

and

$$-I_{CO}(e^{q\Phi_C/kT} - 1) = \alpha_N I_E + I_C. \tag{19}$$

This latter set of equations is more useful for the solution of some nonlinear problems than is the previous pair. It is apparent that one of the four measurable quantities in either set of equations can be eliminated by the use of (15).

## EQUIVALENT CIRCUITS

Eqs. (16) and (17) describe the dc behavior of junction transistors provided the assumptions made in the analysis are satisfied. However, the addition of linear circuit elements to an ideal[7] transistor, account for many of the departures of practical transistors from the assumptions. The principal departures of practical transistors from the ideal case are:

1. The reverse characteristics of the junctions have a finite slope.
2. The semi-conductor regions have finite resistivities, resulting in transverse voltage drops.
3. The alpha is not constant, being a function of both current and voltage.

Applications of (16) and (17) will be made separately to each large signal region of operation, making suitable approximations and adding linear circuit elements when needed to modify the ideal equivalent circuit to account for the behavior of practical transistors.

In Regions I and II, as discussed in the introduction, the collector junction is reverse biased. If the reverse bias is greater than a few tenths of a volt, (16) and (17) become

$$I_E = \frac{I_{EO}}{1 - \alpha_N \alpha_I}(e^{q\Phi_E/kT} - 1) - \frac{\alpha_I I_{CO}}{1 - \alpha_N \alpha_I} \tag{20}$$

$$I_C = +\frac{\alpha_N I_{EO}}{1 - \alpha_N \alpha_I}(e^{q\Phi_E/kT} - 1) + \frac{I_{CO}}{1 - \alpha_N \alpha_I}. \tag{21}$$

---

[6] It is observed that in some cases transistor parameters vary with applied voltage. Best agreement with relation (15) is obtained if the parameters are measured at zero voltage.

[7] By an ideal transistor is meant one which satisfies the terminal relations (16) and (17).

Eqs. (20) and (21) apply whether the emitter is reverse biased or forward biased, and hence apply to both Regions I and II. Eqs. (20) and (21) can be simplified as follows:

$$I_E = -\frac{I_{EO}}{1-\alpha_N\alpha_I}e^{q\Phi_E/kT} + \frac{(1-\alpha_N)I_{EO}}{1-\alpha_N\alpha_I} \tag{22}$$

and

$$I_C = -\alpha_N I_E + I_{CO}. \tag{23}$$

Eqs. (22) and (23) lead to the equivalent circuit shown at the top of Fig. 5. In this circuit base resistance, $r_B$, and collector and emitter junction leakage resistances, $r_{CL}$ and $r_{EL}$, have been added to account for the finite resistivity of the semi-conductor and the finite junction conductances. For small, low-frequency, ac signals, this reduces to the equivalent circuit shown at the bottom of Fig. 5 where

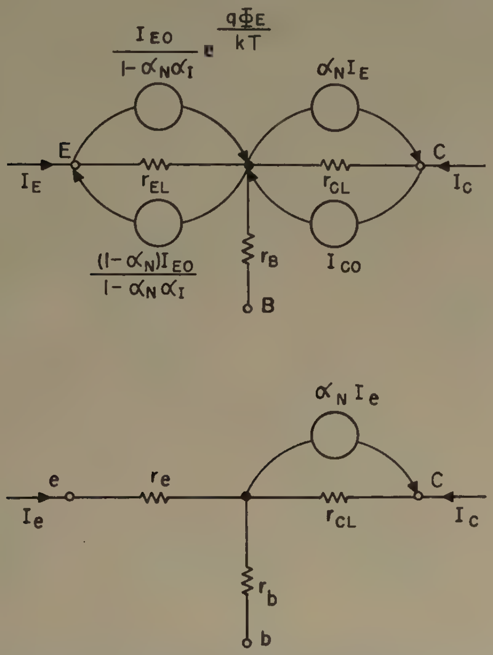
$\frac{I_{EO}}{1-\alpha_N\alpha_I}e^{\frac{q\Phi_E}{kT}}$
$\alpha_N I_E$
E
C
$I_E$
$r_{EL}$
$r_{CL}$
$I_C$
$\frac{(1-\alpha_N)I_{EO}}{1-\alpha_N\alpha_I}$
$r_B$
$I_{CO}$
B
$\alpha_N I_e$
e
$r_e$
C
$I_e$
$r_{CL}$
$I_c$
$r_b$
b

Fig. 5—Equivalent circuit of junction transistor valid in Regions I and II, and the small-signal equivalent circuit.

$$r_e \simeq \frac{\frac{kT}{q}}{I_E - \frac{I_{EO}}{1-\alpha_N\alpha_I}} = \frac{0.026}{I_E - \frac{I_{EO}(1-\alpha_N)}{1-\alpha_N\alpha_I}}. \tag{24}$$

The boundaries of the three large signal regions are of particular interest since the transistor properties change very rapidly when the operating point approaches a boundary. There exists some choice as to which characteristic is used to define the large signal regions. Since the grounded base collector characteristic is the most widely published, it will be used for this purpose. It is convenient to define the boundary between Regions I and II as the curve for $I_E=0$. However, it is true that the transfer characteristic is relatively constant even for reverse values of emitter current. The "low current" boundary of Region I is of course a limit to possible quiescent operating points for the transistor. Mathematically, this boundary is obtained by assuming a large reverse bias on the emitter, and is realized practically by application of a few tenths of a volt reverse bias. The transistor has its smallest conductance in the collector circuit when the emitter has at least a few tenths of a volt reverse bias. The currents under this condition are

$$I_E = +\frac{I_{EO}(1-\alpha_N)}{1-\alpha_N\alpha_I} \tag{25}$$

$$I_C = +\frac{I_{CO}(1-\alpha_I)}{1-\alpha_N\alpha_I}. \tag{26}$$

As a typical example, assume that for a given transistor $\alpha_N=0.9$, $\alpha_I=0.45$, $I_{CO}=2$ μa and $I_{EO}=1$ μa (actually only three of these quantities need be specified). Provided the leakage resistances are negligible, the currents that will flow then under the condition of both junctions being reverse biased are, $I_C=1.85$ μa and $I_E=0.17$ μa. In this case it is seen that the sum of the two currents is approximately $I_{CO}$.

In terms of the grounded base collector characteristics, the boundary between Regions II and III is at $V_C=0$.

In Region III both emitter and collector junctions are forward biased. The collector and emitter are such low impedances that the currents are determined by the external circuit and it is most convenient to consider the currents as independent variables. By this same argument the voltages across the two junctions are seen to be the unknown quantities. These voltages can be obtained from (18) and (19)

$$\Phi_E = \frac{kT}{q}\ln\left[-\frac{I_E+\alpha_I I_C}{I_{EO}}+1\right], \tag{27}$$

and

$$\Phi_C = \frac{kT}{q}\ln\left[-\frac{I_C+\alpha_N I_E}{I_{CO}}+1\right]. \tag{28}$$

It should be recalled from the definitions of $\Phi_E$ and $\Phi_C$ that they are the voltage of the $p$ material relative to the $n$ material. Hence these equations apply for both $n$-$p$-$n$ and $p$-$n$-$p$ transistors. For any reasonable values of $I_E$ and $I_C$ in Region III, these equations become

$$\Phi_E = \frac{kT}{q}\ln\left[-\frac{I_E+\alpha_I I_C}{I_{EO}}\right] \tag{29}$$

and

$$\Phi_C = \frac{kT}{q}\ln\left[-\frac{I_C+\alpha_N I_E}{I_{CO}}\right]. \tag{30}$$

Eqs. (27) and (28) lead to the equivalent circuit shown at the top of Fig. 6 (next page). Base spreading resistance $r_{BIII}$ has been added in this circuit. This resistance is the base resistance as measured in the current saturation region. For nonsymmetric transistors this resistance may be as much as a factor of ten smaller than base resistance measured in the active region. This results from at least two factors:

1. In Region III the center of the emitter junction is not biased as far in the forward direction as is the outer edge of the emitter and, hence, the emitted carriers come from the outer portions of the emitter, and
2. A large part of the base current actually comes from current that is emitted by the collector since it is forward biased.

In the circuit at the bottom of Fig. 6 resistances $r_{Ev}$ and $r_{Cv}$ have been added to account for the body (volume) resistance of the emitter and collector regions.

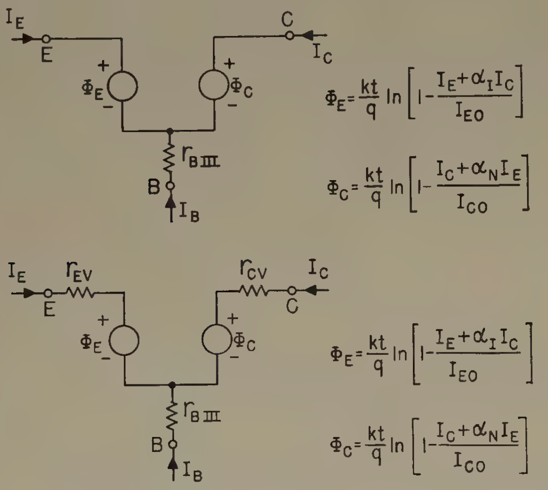
$I_E$
E
C
$I_C$
+
$\Phi_E$
$\Phi_C$
$r_{BIII}$
B
$I_B$
$\Phi_E = \frac{kt}{q}\ln\left[1 - \frac{I_E + \alpha_I I_C}{I_{EO}}\right]$
$\Phi_C = \frac{kt}{q}\ln\left[1 - \frac{I_C + \alpha_N I_E}{I_{CO}}\right]$
$r_{EV}$
$r_{CV}$

Fig. 6—Equivalent circuit of junction transistor valid in Region III.

## GROUNDED EMITTER AND GROUNDED COLLECTOR OPERATION

A large part of the discussion up to this point has been concerned with grounded base operation in that emitter and collector currents have been either the dependent or independent variables. In this section grounded emitter operation will be considered. Fig. 10(b) illustrates a grounded emitter circuit which might be used as a switch or pulse amplifier. The impedances in the open (emitter cutoff) and closed (current saturation) conditions are of interest. The problem is relatively easy in that the equations already available need only be rewritten in terms of the base current. The positive sense of the three currents is defined as being into the transistor, hence

$$I_E + I_B + I_C = 0. \qquad (31)$$

Using this definition and (16) and (17), it can be shown that

$$I_C = +\frac{\alpha_N}{1-\alpha_N} I_B - \frac{I_{CO}}{1-\alpha_N}\left(e^{q\Phi_C/kT} - 1\right). \qquad (32)$$

This equation is valid in all regions of operation. The voltage drop between collector and emitter in Region III, neglecting $r_{Ev}$ and $r_{Cv}$, can be obtained from (29) and (30). This voltage drop expressed in terms of base and collector current is

$$V_{CE} = (\pm)(\Phi_C - \Phi_E)$$

$$= (\pm)\frac{kT}{q}\ln\frac{\alpha_I\left(1 - \frac{I_C}{I_B}\frac{1-\alpha_N}{\alpha_N}\right)}{1 + \frac{I_C}{I_B}(1-\alpha_I)}. \qquad (33)$$

In (33) the (+) sign applies to *p-n-p* transistors and the (−) sign to *n-p-n* transistors.

Eq. (33) gives the voltage drop across the transistor switch in the "closed" condition. Since $kT/q = 0.026$ volt at room temperature, this voltage can be *as low as* a few millivolts. As the collector current approaches $\alpha_N/(1-\alpha_N)I_B$, the voltage in (33) approaches infinity, and the transistor goes from Region III into Region II, which is exactly as would be expected.

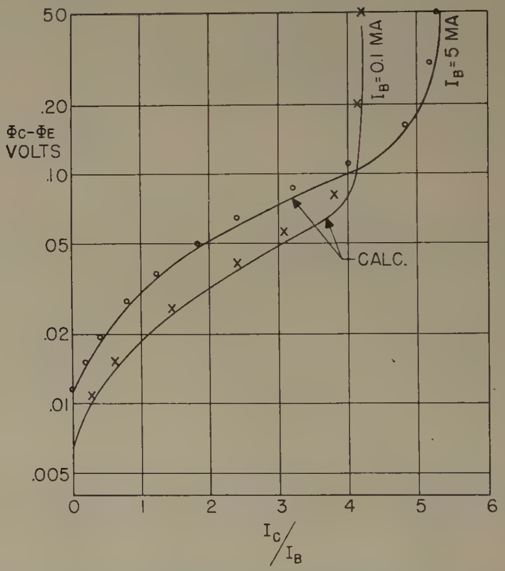

Fig. 7—Voltage drop across a transistor switch as a function of load current. Symmetrical transistor.

Measurements obtained of the variation of $V_{CE}$ with $I_C/I_B$ for a symmetric transistor are shown in Fig. 7. For the calculated curve, $\alpha_N$ and $\alpha_I$ were measured over a wide range of values of $I_E$ and $I_C$, respectively. This data, shown in Fig. 8 (facing page), was obtained by measuring the ratio

$$\alpha_N = \frac{I_C}{I_E}, \qquad (V_{CB} = 0)$$

or

$$\alpha_I = \frac{I_E}{I_C}, \qquad (V_{EB} = 0).$$

The variation in $\alpha_N$ and $\alpha_I$ were included in the calculations.

Similar measurements for an unsymmetric transistor (area of collector greater than area of emitter) are

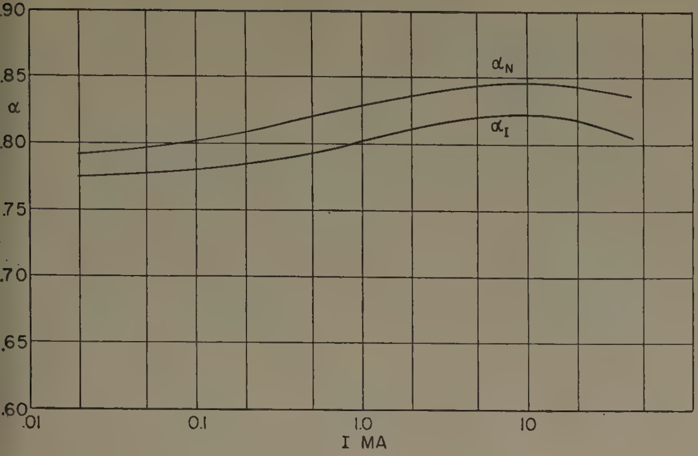

Fig. 8—Variation of the dc alphas as a function of emitter current for a symmetric transistor.

shown in Fig. 9. The calculated curve in this case assumed constant $\alpha_N$ and $\alpha_I$.

In general it has been found that better agreement between theory and experiment is obtained if the current levels are low. Also $n$-$p$-$n$ alloy transistors are more "theoretical" than $p$-$n$-$p$ alloy transistors since $\alpha_N$ and $\alpha_I$ are more constant with emitted current. It is believed that the theory is of sufficient accuracy for low-level applications, such as when the transistor is used as a clamping device in coding. In the case of transistors of the 50 mw class being used as pulse amplifiers at currents as high as 100 ma, the error may be as large as 100 per cent.

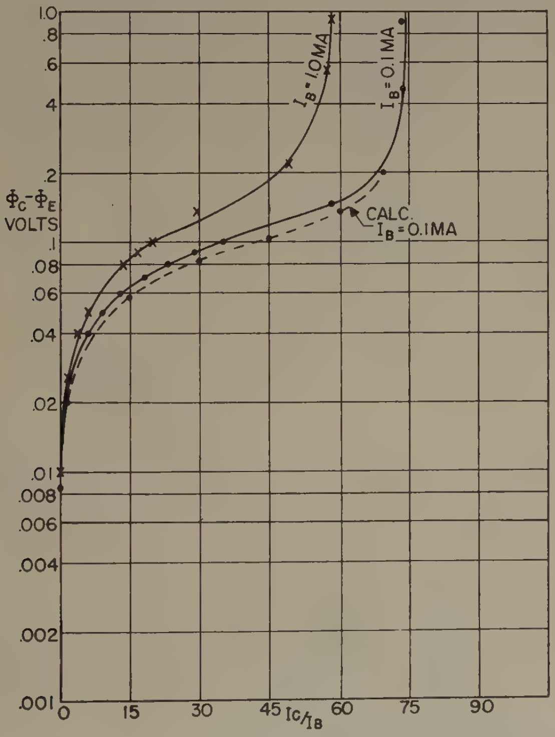

Fig. 9—Voltage drop across a transistor switch as a function of load current. Unsymmetric transistor.

The ac impedance in the collector circuit in the closed condition is obtained by taking the derivative of $(\Phi_C - \Phi_E)$ with respect to $I_C$. This is

$$\frac{dV_{CE}}{dI_C} = (\pm)\frac{kT}{q}\left[\frac{1-\alpha_N}{\alpha_N\left(I_B - I_C\,\dfrac{1-\alpha_N}{\alpha_N}\right)} + \frac{1-\alpha_I}{I_B + I_C(1-\alpha_I)}\right]. \quad (34)$$

In (34) the $(-)$ sign applies to $p$-$n$-$p$ transistors and the $(+)$ sign to $n$-$p$-$n$ transistors.

For $\alpha_N$ and $\alpha_I$ close to one and moderately large values of $I_B$ the ac resistance in Region III may be of the order of an ohm.

In order to "open" the transistor switch, a base bias is applied to bias the emitter junction in reverse. The "open circuit" collector current is given by (26) and is in general less than $I_{CO}$. Also the ac impedance between the emitter-collector terminals is at least $r_{CL}$. The importance of the bias on the base terminal is illustrated by considering the impedance in the collector circuit when the base current is zero. In this case the collector current is $I_{CO}/(1-\alpha_N)$ and the ac impedance looking in the collector to emitter terminals is $r_{CL}(1-\alpha_N)$. The application of a voltage to the base, which also reverse biases the emitter junction, considerably increases the open circuit impedance.

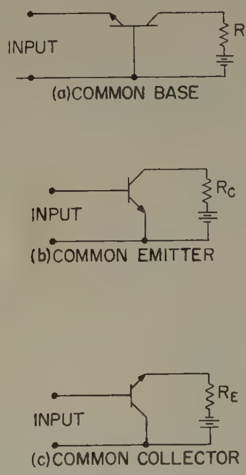

Fig. 10—Transistor switching circuits.

The transistor can also be used as a switch or pulse amplifier in the grounded collector connection as shown in Fig. 10(c). It is convenient to express voltages in the saturation region in terms of emitter and base current. Thus

$$V_{EC} = (\pm)(\Phi_E - \Phi_C) = (\pm)\frac{kT}{q}\ln\frac{\alpha_N\left(1 - \dfrac{1-\alpha_I}{\alpha_I}\,\dfrac{I_E}{I_B}\right)}{1 + (1-\alpha_N)\,\dfrac{I_E}{I_B}}. \quad (35)$$

In (33) the (+) sign applies to *p-n-p* transistors and the (−) sign to *n-p-n* transistors. The ac impedance is

$$\frac{dV_{EC}}{dI_B} = (\pm)\frac{kT}{q}\left(\frac{1-\alpha_N}{(1-\alpha_N)I_E + I_B} + \frac{1-\alpha_I}{\alpha_I I_B - (1-\alpha_I)I_E}\right), \tag{36}$$

where the (−) sign applies to *p-n-p* transistors and the (+) sign to *n-p-n* transistors.

For the "open" circuit condition the considerations are slightly different from the grounded emitter connection, since it is possible to reverse the direction of the load current. The highest impedance in the emitter-collector circuit is obtained when both junctions are reverse biased.

For some applications there is a significant difference between grounded emitter and grounded collector operation in that the grounded collector amplifier has no voltage gain. In the circuit of Fig. 10(c), if, for example, the emitter supply voltage is +10 volts, the base voltage must be of the order of $+10\frac{1}{2}$ volts to hold the transistor in the cut-off condition. To be in the current saturation region, approximately $-\frac{1}{2}$ volt is required on the base lead. Thus, a pulse amplitude of approximately 11 volts is required to drive the transistor from the cutoff to saturation region. The output voltage is then slightly less than the driving voltage. This is in contrast to the common emitter connection in which there is, of course, voltage gain.

An important feature of the junction transistor is that if it is almost symmetrical it can be used to switch voltages of either polarity.[8] In the circuit of Fig. 10(b), if the collector battery has the polarity shown, the transistor is operating in the normal grounded emitter circuit. If the supply voltage is reversed, the emitter functions as the collector and the collector as the emitter. Except for the amount of driving voltage required, the operation of the switch is independent of the polarity of the voltage to be switched. In order to keep the switch off, it is necessary that the bias on the base be more negative than the most negative voltage which appears in the collector circuit. Thus, if random voltages are to be switched with this circuit, it is not possible to have voltage gain in the switch. If the switch driving current is constant and independent of polarity of the voltage to be switched, it should be true for optimum operation that

$$\frac{\alpha_N}{1-\alpha_N} = \frac{1}{1-\alpha_I} \tag{37}$$

or

$$\alpha_I = 2 - \frac{1}{\alpha_N}\,. \tag{38}$$

As an example, if $\alpha_N = 0.8$, then $\alpha_I$ should be about 0.75.

## SWITCHING TIMES[9]

The time required to change the operating point of a junction transistor from Region I to Region III, or vice versa, is clearly of primary importance. This time (switching-time) is one of the major limitations in the application of junction transistors. It is the purpose of this section to show how switching-time is related to transistor parameters and circuit conditions. First a general description of large-signal transient phenomena is required, followed by a more detailed discussion. The discussion will be limited to resistive loads, as in Fig. 10. Fig. 13 shows the transient which occurs when a large signal pulse of current is applied to the base lead of a transistor in the common emitter connection. It is assumed that the original operating point of the transistor is in Region I and the final operating point is in Region III (current saturation). The collector current starts out along an exponential rise determined by the amount of drive (current gain) and the frequency response of the transistor. (In the common emitter connection the cut-off frequency is $[(1-\alpha_N)f_N]$. When the operating point enters the current saturation region the collector voltage reverses its sign. The low resistance of the forward biased collector prevents the total collector current from increasing appreciably, and the current remains constant at very nearly $V_{cc}/R_c$. The switching-time is easily calculated in terms of the normal active region parameters of the transistor. For the case where the load impedance is low enough that collector capacitance does not limit turn-on time, the turn-on time is given by[10]

$$t_0 = \frac{1}{\omega_N}\ln\frac{I_E}{I_E - \dfrac{0.9I_C}{\alpha_N}} \quad \text{(common base)} \tag{39}$$

$$t_0 = \frac{1}{(1-\alpha_N)\omega_N}\ln\frac{I_B}{I_B - 0.9\dfrac{(1-\alpha_N)I_C}{\alpha_N}} \quad \text{(common emitter)} \tag{40}$$

where

$t_0$ = time for current to reach 90 per cent of its limiting value
$I_E$ = emitter current after step has been applied (common base)
$I_B$ = base current after step has been applied (common emitter)
$I_C$ = limiting value of collector current
$\alpha_N$, $\omega_N$ = current gain and frequency cutoff.

For the common collector connection

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[8] This was pointed out to us by P. A. Reiling.

[9] A more complete theoretical treatment of large-signal switching-times is given in J. L. Moll "Large-signal transient behavior of junction transistors," PROC. I.R.E., pp. 1773–1784, this issue. This section contains an abstraction of the more complete treatment of transient behavior along with some special considerations pertinent to switching applications.

[10] The use of $\alpha_N$ and $\alpha_I$ in these and subsequent equations is not strictly correct. However, the discrepancy between the dc and the small signal current gains are sufficiently small, such that the error is insignificant.

$$t_0 = \frac{1}{(1-\alpha_N)\omega_N} \ln \frac{\alpha_N I_B}{I_B - 0.9\,\dfrac{(1-\alpha_N)I_E}{\alpha_N}} \qquad (41)$$

where

$I_B$ = base current after step has been applied

$I_E$ = limiting value of emitter current.

Turn-on time clearly depends on the amount of drive, current gain, and frequency response of the transistor. In order to compare the common emitter and common base connections, turn-on time has been plotted as a function of driving current for a special case in Fig. 11. It is seen from this plot that for equal driving currents, the common emitter connection switches on faster than the common base circuit. In addition, at some sacrifice in speed, a given current can be controlled with smaller drive for the common emitter case.

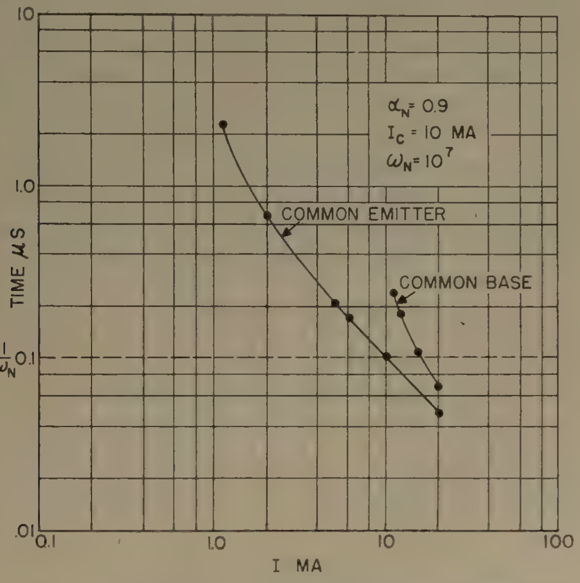

Fig. 11—Turn-on time as a function of driving current.

The turn-off transient from Region III to Region I differs materially from the turn-on transient in that the junction transistor suffers from carrier storage. The phenomenon of carrier storage has been noted in point contact transistors and in point contact and junction rectifiers. The way in which carrier storage manifests itself in junction transistors is illustrated in Fig. 13. The succession of events during the turn-off transient (at end of pulse) may be described as follows. The base (or emitter) current is reduced from a value corresponding to operation in Region III to zero, or possibly to a reverse emitter junction current. The excess carrier density in the base layer decays until the minority carrier density in the base layer at the collector junction reaches nearly zero. During this initial stage of the turn-off transient, the collector junction is a low impedance and the collector current remains very nearly constant, at a value determined by the external circuit resistance. When the minority carrier density in the base layer at the collector approaches zero, the collector junction rapidly becomes a high impedance. The turn-off transient, after the collector junction has "recovered," is controlled by the normal active region parameters. We see that for junction transistors the turn-off transient can be conveniently divided into two times: Storage time is the time interval between the reduction of base (or emitter) current to a zero, or reverse value, and the active response of the collector current. This time is labeled $t_1$ in Fig. 13. Decay time is the time between the beginning of active response of the collector current and the time when the collector reaches 10 per cent of its Region III value. Decay time is labeled $t_2$ on Fig. 13. Actually, this picture is a slight oversimplification of the turn-off transient. The collector junction requires a finite time to change from a low impedance to a high impedance. This manifests itself in a rounding-off of the transition between the recovery time and the delay time. For practical considerations, however, the description in terms of storage time and decay time is sufficiently accurate. If the reverse emitter current during turn-off is larger than the reverse collector current, the emitter junction may recover before the collector junction. In this case the qualitative picture is somewhat changed from that given above. The analysis given here is concerned with more moderate turn-off currents.

Storage time has been related to transistor parameters and circuit conditions[11] from fundamental considerations. If the width of the turn-on pulse is as great or greater than the time constant $1/(1-\alpha_N)\omega_N$, the carrier density reaches equilibrium. In this case approximate expressions for storage time are:

$$t_1 = \frac{\omega_N + \omega_I}{\omega_N\omega_I(1-\alpha_N\alpha_I)} \ln \frac{I_{E2} - I_{E1}}{\dfrac{I_{C1}}{\alpha_N} + I_{E2}} \quad \text{(common base)} \quad (42)$$

$$t_1 = \frac{\omega_N + \omega_I}{\omega_N\omega_I(1-\alpha_N\alpha_I)} \ln \frac{I_{B1} - I_{B2}}{\dfrac{I_{C1}(1-\alpha_N)}{\alpha_N} - I_{B2}} \quad \text{(common emitter)} \quad (43)$$

$$t_1 = \frac{\omega_N + \omega_I}{\omega_N\omega_I(1-\alpha_N\alpha_I)} \ln \frac{I_{B2} - I_{B1}}{I_{B2} + I_{E1}(1-\alpha_N)} \quad \text{(common collector)} \quad (44)$$

where

$\alpha_N$, $\omega_N$ = normal alpha, and cut-off frequency of normal alpha

$\alpha_I$, $\omega_I$ = inverted alpha, and cut-off frequency of inverted alpha

$I_{E1}$, $I_{E2}$ = emitter current before, after turn-off step is applied (common base)

$I_{C1}$ = initial collector current (common base and common emitter)

$I_{B1}$, $I_{B2}$ = base current before, after turn-off step is applied (common emitter and common collector)

$I_{E1}$ = initial emitter current (common collector).

The decay time is obtained from the normal small signal active region parameters. The time for the load current to decay to 10 per cent of its initial value is

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[11] J. L. Moll, "Large signal transient behavior of junction transistors," Proc. I.R.E., pp. 1773–1784, this issue.

$$t_2 = \frac{1}{\omega_N} \ln \frac{I_{C1} + \alpha_N I_{E2}}{\frac{1}{10} I_{C1} + \alpha_N I_{E2}} \quad \text{(common base)} \tag{45}$$

$$t_2 = \frac{1}{(1-\alpha_N)\omega_N} \ln \frac{I_{C1} - \frac{\alpha_N}{1-\alpha_N} I_{B2}}{\frac{1}{10} I_{C1} - \frac{\alpha_N}{1-\alpha_N} I_{B2}} \quad \text{(common emitter)} \tag{46}$$

$$t_2 = \frac{1}{(1-\alpha_N)\omega_N} \ln \frac{I_{E1} - \frac{I_{B2}}{1-\alpha_N}}{\frac{1}{10} I_{E1} - \frac{I_{B2}}{1-\alpha_N}} \quad \text{(common collector)} \tag{47}$$

where the symbols have the same meanings as before. These relations show that storage time in junction transistors is a function not only of the normal parameters but also of the inverted alpha and frequency cutoff. In symmetric transistors the coefficient in (42) to (44) is

$$\frac{\omega_N + \omega_I}{\omega_N \omega_I (1 - \alpha_N \alpha_I)} \cong \frac{1}{\omega_N (1 - \alpha_N)}, \tag{48}$$

and depends only on the normal alpha and frequency response. In unsymmetric alloyed transistors the coefficient may be anywhere from about $\frac{1}{5}$ to 5 times the right-hand side of (48). In grown junctions the coefficient may be as much as 100 times the right-hand side of (48) because of carrier storage in the collector region.

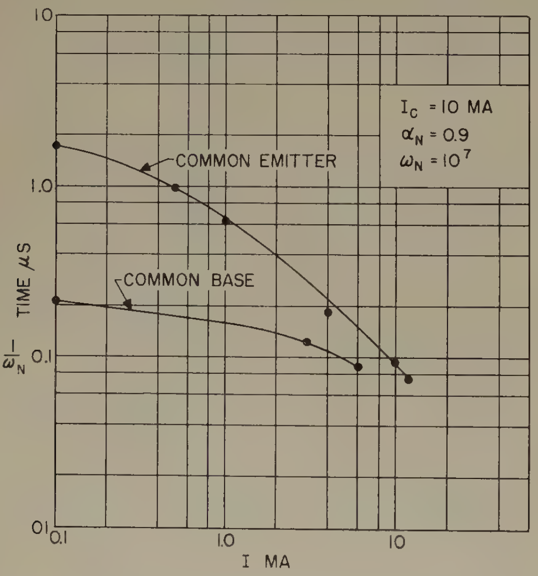
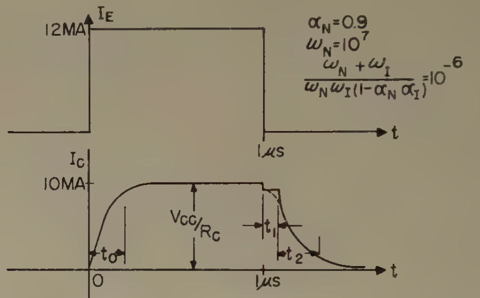
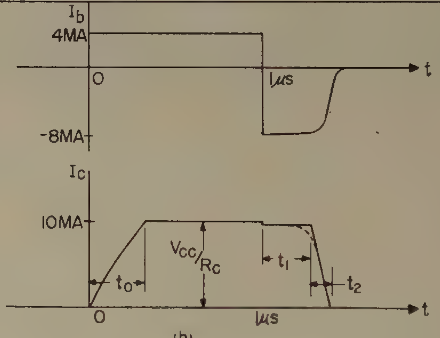


Fig. 12—Decay time as a function of reverse driving current during turn-off.

In order to obtain a comparison between common emitter and common base operation, the decay time for the transistor of Fig. 11 is plotted in Fig. 12 as a function of reverse current during turn-off. It must be emphasized that the base-emitter circuit remains a low impedance throughout the turn-off transient, and the current across the emitter junction may be in the reverse direction for most of the duration of the transient. Fig. 13 shows transient behavior for the cases of common emitter and common base connections for the transistor of Figs. 11 and 12. In each case the increment of driving current is 12 ma and the collector current is limited at 10 ma. This figure illustrates the fact that if suitable bias conditions are chosen and the increment of driving current is the same for the two connections, the switching-time for the common emitter connection can be made almost the same as for the common base connection. For the purposes of this illustration it was assumed that the transistor was symmetric. All of the times in Figs. 11, 12, and 13 are within one order of magnitude of $1/\omega_N$ and it is true, in general, that for symmetric transistors the frequency cutoff $\omega_N$ is the most important parameter governing switching speed. For unsymmetrical transistors the product $(1-\alpha_I)\omega_I$ is important in determining the storage time. For most unsymmetric alloyed transistors now being developed, $\omega_N \gg \omega_I$ and $(1-\alpha_N) \ll 1-\alpha_I$.



(a)
TRANSIENT (COMMON BASE)



(b)
TRANSIENT (COMMON EMITTER)

Fig. 13—Transient behavior of junction transistors.

$$\frac{\omega_N + \omega_I}{\omega_N \omega_I (1 - \alpha_N \alpha_I)} \cong \frac{1}{\omega_I (1 - \alpha_I)}. \tag{49}$$

The four quantities $\alpha_N$, $\omega_N$, $\alpha_I$, $\omega_I$ can be varied independently to some extent. Thus reduction of $\alpha_I$ and increase of $\omega_I$ should decrease the storage time of the transistor. In general, $\omega_I < \omega_N$ so that to increase $\omega_I$ one must increase $\omega_N$. Also, the designs which decrease $\alpha_I$ will increase $I_{c0}$ and in general tend to decrease $\omega_I$. Decreasing $\alpha_I$ also increases the emitter to collector voltage drop and ac impedance. Clearly, the best compromise of these parameters depends on the specific application.

The effect of collector capacitance and base resistance on switching-time has not been considered as yet. The initial surge of controlling current passes through the base resistance so that the driving power required for a given current increases in proportion to the base resistance. For practical cases almost the entire voltage drop at the input electrodes results from the base resistance.

The effect of collector capacitance is to increase the switching-time. If it is true that

$$R_cC_c\omega_N \ll 1,$$

then collector capacitance does not significantly affect switching-time.

## EXAMPLE OF APPLICATION OF THEORY

For many large-signal problems it may be difficult to obtain a complete analysis. However, it is usually possible to obtain a solution to various parts of relatively complicated problems. In some cases, where it is not easy to obtain a simple expression which does not involve exponentials relating current to voltage, a maximum or minimum can be obtained by differentiation. Information regarding a maximum or a minimum may be all that is important in some cases.

Fortunately good approximations to functions of the form ($q^{\Phi}/e^{kT}-1$) can be obtained, which give results which agree well with experiment over wide ranges of current and voltage. As an example, consider the simple circuit shown in Fig. 14. This configuration occurs frequently in switching (and transmission) circuits. It is desired to obtain an expression for $I_C$ as a function of $R$. It is assumed that the collector junction is reverse biased and that the emitter junction is biased slightly in the forward direction. For small values of emitter bias, a good approximation is

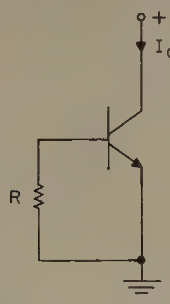


Fig. 14—Transistor circuit.

$$\left(\frac{q^{\Phi_E}}{e^{kT}-1}\right) = \frac{q}{kT}\,\Phi_E. \tag{50}$$

Using the results of the preceding sections, the following equation can be obtained relating the collector current to the constants of the transistor and $R$.

$$I_C = -\frac{I_{CO}}{1-\alpha_N\alpha_I}\left[1+\frac{\alpha_N(1-\alpha_I)}{(1-\alpha_N)+\dfrac{kT}{q}\,\dfrac{(1-\alpha_N\alpha_I)}{I_{EO}R}}\right]. \tag{51}$$

For $R=0$ this becomes

$$I_C = -\frac{I_{CO}}{1-\alpha_N\alpha_I}, \tag{52}$$

and for $R=\infty$

$$I_C = -\frac{I_{CO}}{1-\alpha_N}. \tag{53}$$

Eqs. (52) and (53) are exact equations which can be derived without the use of assumption (50) by going back to (16) and (17). Thus it is seen that by using this assumption a result can be obtained which is exact for the extreme values of $R$ and is an excellent approximation for intermediate values of $R$. Measured and calculated curves of $I_C$ as a function of $R$ are shown in Fig. 15.

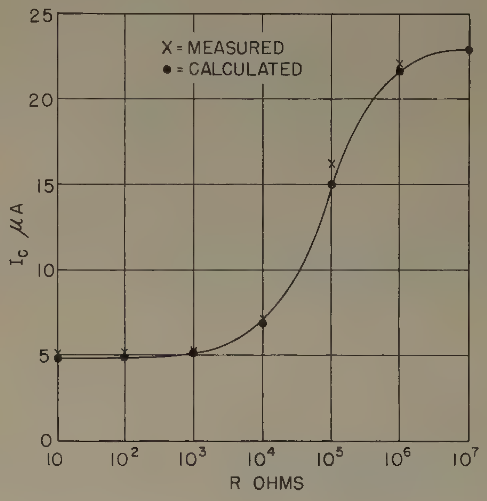


Fig. 15—Data on circuit of Fig. 14.

## APPENDIX

### PROOF OF GENERAL TRANSISTOR RELATIONS

It is the purpose of this Appendix to prove the following general transistor relations.[12]

$$I_E(\Phi_E,\ \Phi_c) = a_{11}(e^{q\Phi_E/kT}-1) + a_{12}(e^{q\Phi_c/kT}-1)$$
$$I_c(\Phi_E,\ \Phi_c) = a_{21}(e^{q\Phi_E/kT}-1) + a_{22}(e^{q\Phi_c/kT}-1). \tag{54}$$

No restrictions will be placed on the shape of the emitter and collector junctions. It will also be shown in this Appendix that $a_{12}=a_{21}$ in (54). As part of the proof, it will be shown that under the conditions of (54), with $\Phi_E$ and $\Phi_c$ volts on the emitter and collector junctions, carrier density can be considered as the sum of densities which would exist under the following conditions:

$$\begin{aligned}&\text{Voltage across emitter junction} = \Phi_E\\ &\text{Voltage across collector junction} = 0\end{aligned} \tag{55}$$

$$\begin{aligned}&\text{Voltage across emitter junction} = 0\\ &\text{Voltage across collector junction} = \Phi_c.\end{aligned} \tag{56}$$

In deriving these relations it will be assumed that the minority carrier density is sufficiently small that carrier flow is governed by the linear diffusion equation, and that there are no drift fields in the base layer except at the junctions. Space-charge layer widening will be neglected. For convenience, $p$-$n$-$p$ transistor geometry will be assumed. (See Fig. 3.) Shockley, Sparks, and Teal[12] have given an excellent theoretical discussion leading to the boundary conditions

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[12] Shockley, Sparks, and Teal, *loc. cit.*, obtained these relations for planar transistors. A general derivation will be given here for completeness, however.

$$\begin{aligned} n &= n_p e^{q\Phi/kT} \\ p &= p_n e^{q\Phi/kT} \end{aligned} \tag{57}$$

for the density of carrier at a boundary with applied voltage, $\Phi$. In this formula,

$n$ = density of electrons just inside $p$-type semiconductor

$p$ = density of holes just inside $n$-type semiconductor

$n_p$, $p_n$ are thermal equilibrium values

$\Phi$ is potential of $p$-type semiconductor relative to $n$-type.

First it will be shown that the solution for carrier density can be written as the sum of solutions of the type as in (55) and (56). The diffusion equation for holes is (neglecting drift fields)

$$D_p\nabla^2 p - \frac{p - p_n}{\tau} = \frac{\partial p}{\partial t}. \tag{58}$$

If $p_n$ varies, at most, slowly as a function of position (resistivity varies slowly as a function of position) so that there are negligible "built in" drift fields, (58) can be written

$$D_p\nabla^2(p - p_n) - \frac{p - p_n}{\tau} = \frac{\partial(p - p_n)}{\partial t}. \tag{59}$$

Similar considerations hold for electron density in $p$-type semiconductor. The boundary conditions on the external surfaces are

$$D_p\nabla p\cdot dS = s(p - p_n)\,|dS|, \tag{60}$$

when $s$ is surface recombination velocity and may be a function of position. (It is assumed that the base contact does not emit holes.) This may be written as

$$D_p\nabla(p - p_n)\cdot dS - s(p - p_n)\,|dS| = 0. \tag{61}$$

The assumption of negligible "built in" field must be used to obtain (61). Hence the external surface boundary condition is linear in $p$-$p_n$ (or $n$-$n_p$ in $p$-type semiconductor). It follows from this that the solution to the differential (59) is a linear function of the densities at the two junctions and is, in fact, the sum of two solutions with boundary conditions as specified in (55) and (56). The currents at the boundaries are

$$I_p = -q\int_s D_p\nabla_p\cdot dS \text{ (in $n$-type semiconductor)}$$

$$I_n = q\int_s D_n\nabla n\cdot dS \text{ (in $p$-type semiconductor)}$$

$$I = I_p + I_n = \text{total current across junction.} \tag{62}$$

The two independent solutions are of the form

$$\begin{aligned} p_1 - p_n &= p_n(e^{q\Phi_E/kT} - 1)f(x, y, z) \\ f &= 0 \quad \text{on } J_2 \\ &= 1 \quad \text{on } J_1 \end{aligned} \tag{63}$$

and

$$\begin{aligned} p_2 - p_n &= p_n(e^{q\Phi_c/kT} - 1)g(x, y, z) \\ g &= 1 \quad \text{on } J_2 \\ &= 0 \quad \text{on } J_1. \end{aligned} \tag{64}$$

If $\Phi_E$ and $\Phi_c$ are simultaneously applied, the density of holes is of the form

$$p - p_n = (p_1 - p_n) + (p_2 - p_n). \tag{65}$$

The electron densities in the two $p$-type semiconductor regions are related to the emitter and collector voltages by relations of the form

$$\begin{aligned} n - n_p &= A(x, y, z)n_{p1}(e^{q\Phi_E/kT} - 1) \\ n - n_p &= B(x, y, z)n_{p2}(e^{q\Phi_c/kT} - 1) \end{aligned} \tag{66}$$

for the emitter and collector regions respectively. The functions $A$ and $B$ are equal to 1 at the junction. The calculations of emitter and collector currents result in relations of the form (54), where the $a_{ij}$ depend on geometry. To prove $a_{12} = a_{21}$, it is necessary to show that

$$I_E(0, \Phi_C) = I_C(\Phi_E, 0)$$

when

$$\Phi_E = \Phi_C. \tag{67}$$

Since the boundary condition at $J_2$ (collector) affects only the hole current at $J_1$, (emitter), and vice-versa, it is necessary only to prove (67) for hole current.

Green's theorem in the form

$$\iiint_V (U\nabla^2 V - V\nabla^2 U)dV = \iint_S (U\nabla V - V\nabla U)\cdot dS \tag{68}$$

will be used. Identify $U$ with $f$, and $V$ with $g$, of (63) and (64). Then the left-hand side of (68) is zero, because the functions satisfy the diffusion (58) with $\partial p/\partial t = 0$. The integrand on the right-hand side is zero on the external surface, because the functions satisfy the boundary condition (61). There results

$$\iint_{J_1} \nabla_g\cdot dS - \iint_J \nabla f\cdot dS = 0. \tag{69}$$

Eq. (67) follows if $p_n$ is the same at emitter and collector junctions.

This proof does not imply that coefficients $a_{ij}$ have the same frequency dependence (in fact they do not). However, two solutions (55) and (56) are independent of each other even during transient or time dependent conditions. The considerations which were applied to two $p$-type semiconducting regions adjacent to an $n$-type base region can be generalized to $N$ $p$-type regions adjacent to an $n$-type base, where $N$ is any specified integer.

# Large-Signal Transient Response of Junction Transistors*

JOHN L. MOLL†, ASSOCIATE, IRE

**Summary—Transient response in the active region for junction transistors can be calculated from the conventional small-signal equivalent circuit. This small-signal characterization is adequate to calculate turn-on time and decay time. Carrier storage time, or time for the transistor operating point to move from the current saturation region to the active region, is calculated from a small-signal characterization of the transistor in the current saturation region. Frequency cutoff of alpha, $\omega_N$ (radians/second) is the most important single transistor parameter affecting switching speed. It is possible with moderate driving current to switch the operating point from collector current cutoff to collector current saturation in times of the order of $3/\omega_N$. To switch from collector current saturation to collector current cutoff, in times of the order of $3/\omega_N$, carrier storage effects must be avoided.**

## INTRODUCTION

THE USE of conventional techniques of analysis makes possible the calculation of small-signal transient response from the small-signal transmission characterization of a device. In fact, relations between Laplace transforms of current and voltage are obtainable directly from the small-signal transmission characterization. The Laplace transform relations can then be used to calculate transient response. The calculation of transient response as outlined above is valid as long as the operating range is linear. For junction transistors, if the operating point is in the active region, the small-signal parameters are sufficiently constant that quite accurate calculations of transient response can be carried out.

If the transistor is driven sufficiently hard to cause the operating point to enter the current saturation region, carrier storage effects must be included in switching-time calculations. The three large-signal regions of the transistor have been defined for junction transistors[1] as follows:

Region I: (collector current cutoff), emitter and collector junctions reverse biased.

Region II: (active) emitter forward and collector reverse biased.

Region III: (current saturation) emitter and collector both forward biased.

Fig. 1 illustrates the minority carrier density along a filament between the emitter and collector in each of these three regions. In Region I (collector current cutoff) the density is very nearly zero at both emitter and collector. In Region II (active) the density is positive at the emitter and very nearly zero at the collector. In Region III (collector current saturation) the density is very high throughout the base layer including in the vicinity of the collector junction. In Region III the collector junction is forward biased[1] and is therefore a very low impedance. In the circuit at the top of Fig. 2, for example, the load current is determined by the external circuit rather than the transistor as long as the operating point is in the current saturation region. The type of response which is encountered is illustrated in the idealized large-signal response in Fig. 2.

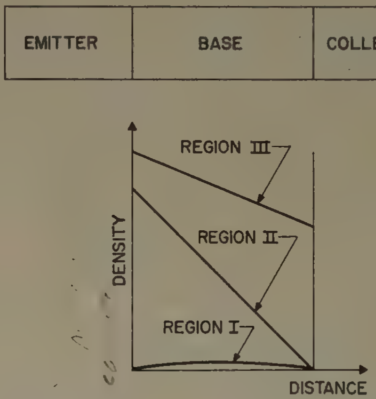

Fig. 1—Carrier density along a filament in the base layer between emitter and collector in the three regions of operation.

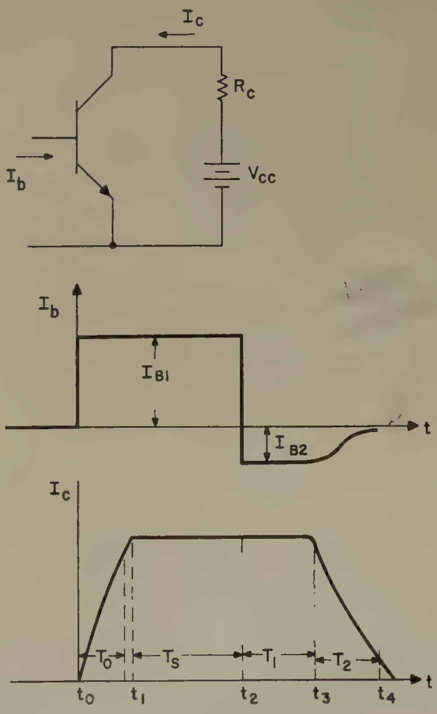

Fig. 2—Response to large-signal pulse of current in the base circuit.

From time $t_0$ to $t_1$ the transistor switch is being "turned on" and the transient is determined by the active region parameters of the transistor. At time $t_1$ the operating point enters the current saturation region.

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* Original manuscript received by the IRE, July 19, 1954.

† Bell Telephone Labs., Inc., Murray Hill, N. J.

[1] J. L. Moll and J. J. Ebers, "Large-signal behavior of junction transistors," PROC. I.R.E., pp. 1761–1772; this issue.

The period of time required for the current to reach 90 per cent of its current saturation value will be called $T_0$ (turn-on time). At time $t_2$ the base current is reduced to a value corresponding to Region I and the turn-off transient begins. From time $t_2$ to $t_3$ the minority carrier density in the base layer is large, corresponding to operation in Region III, but is decaying towards zero. During this time ($t_2$ to $t_3$), the collector is a low impedance and collector current is determined by the external circuit. At time $t_3$ the carrier density near the collector junction is very nearly zero. At this point the collector junction impedance increases rapidly and the transistor begins to react with its active region parameters. The time interval from $t_2$ to $t_3$ will be called $T_1$, the carrier storage time. After time $t_3$ the transient behavior is calculated from the active region parameters. At time $t_4$, on Fig. 2, the collector current has decayed to 10 per cent of its maximum value. The interval of time from $t_3$ to $t_4$ will be called $T_2$, the decay time.

A large class of large-signal transient problems can be described qualitatively by the events as outlined in Fig. 2. The essential analytical problems in this type of transient are the calculation of the times $T_0$, $T_1$, and $T_2$. The times $T_0$ and $T_2$ are calculated from the active region parameters of the transistor, and can be obtained from the application of standard techniques of circuit analysis to the active region equivalent circuit of the transistor. Examples of transient response calculations in the active region are included for completeness.

The calculation of $T_1$, the carrier storage time, requires the calculation of the transition time from the current saturation region to the active region. It is possible, in principle, to calculate the carrier storage time from the diffusion equation which governs minority carrier density in semiconductors. This calculation, however, is a formidable one—especially for nonplanar transistors. An alternative physical picture and formulation of the problem, presented in a later section, avoids the necessity of solving the diffusion equation and hence is amenable to calculation. The theory of transient response will be divided into sections as follows: (a) Small-signal behavior in the active region; (b) Small-signal behavior in the current saturation region; (c) Large-signal switching-times.

## THEORY

### *Small-Signal Transient Response in the Active Region*

Fig. 3 illustrates an equivalent circuit which satisfactorily describes the small-signal transient behavior of junction transistors. This is the usual small-signal equivalent circuit, with neglect of space-charge layer widening effects[2] except insofar as they affect the magnitudes of the components of the equivalent circuit of Fig. 3. The capacitance $C_{se}$ in the emitter admittance $Y_e$ is the usual diffusion capacitance[3] associated with minority carrier density in the base layer.

The representation of a physical device by an equivalent circuit, of course, has limitations. In particular, the equivalent circuit of Fig. 3 is limited to a finite bandwidth and range of operating biases. The range of application of an equivalent circuit must in general be balanced against the complexity of the circuit. The simpler the equivalent circuit the more limited is its range of application. The circuit of Fig. 3 is sufficiently accurate to describe the transient behavior of transistors to a time definition of $1/\omega_N$ to $1/10\omega_N$, depending on the circumstances.[4] In general this accuracy is all that is warranted. Any simplification of the circuit results in extreme limitation of its application. Any further complication results in prohibitive analytical difficulties in applications to circuits. Thus this circuit is a good compromise between utility and complexity.

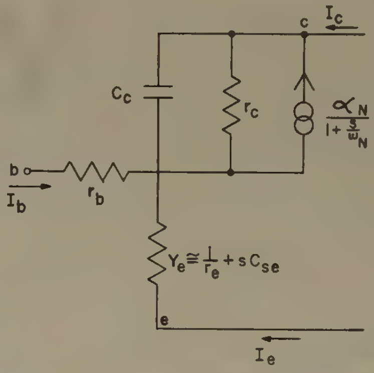
c
$I_c$
$C_c$
$r_c$
$\frac{\alpha_N}{1+\frac{s}{\omega_N}} I_e$
b
$I_b$
$r_b$
$Y_e \cong \frac{1}{r_e} + sC_{se}$
e
$I_e$

Fig. 3—Small-signal equivalent circuit suitable for calculation of transient response. For planar transistors, $C_{se} \cong 1/1.5 r_e \omega_\alpha$.

how about large signal transient

The general case of small-signal transient becomes very complicated, but some special cases of interest will be presented here. In particular, common (or grounded) emitter, common base, and common collector circuits, under conditions which approximate short-circuited output conditions, will be analyzed. Fig. 4 (opposite) illustrates these circuits. It will be assumed throughout that $\alpha$ has the form

$$\alpha(s) = \frac{\alpha_N}{1 + s/\omega_N} \qquad (1)$$

where $\alpha_N$ = value at zero frequency and $\omega_N$ = radian cutoff frequency of alpha. In keeping with Laplace transform notation, $s$ is a complex variable. The assumed frequency dependance of alpha is of course an approximation to the actual case. Experience has shown, however, that it is a satisfactory approximation. For the case of grounded base operation the current gain and input admittance are very nearly their short circuit values if

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[2] J. M. Early, "Effect of space charge layer widening in junction transistors," Proc. I.R.E., vol. 40, pp. 1401–1406; November, 1952.

[3] J. M. Early, "Design theory of junction transistors," *Bell Sys. Tech. Jour.*, vol. XXXII, pp. 1271–1312; November, 1953.

[4] $\omega_N$, $\alpha_N$, $\omega_I$ and $\alpha_I$ are used in this paper with the same meaning as in reference 1, to refer to normal and inverted transistor operation.

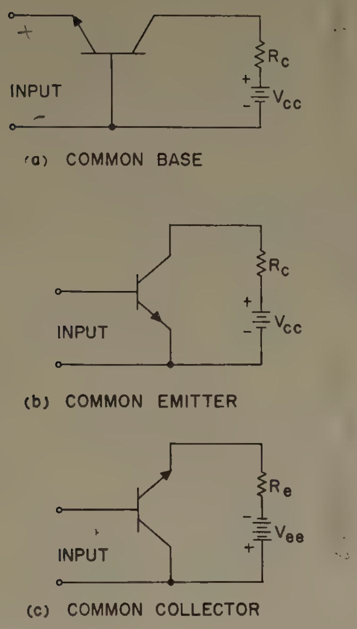

Fig. 4—Transistor amplifying or switching circuits.

$$\left(\frac{1}{r_c} + \omega_N C_c\right)(r_b + R_c) \ll 1. \quad (2)$$ ✓

For this case,

$$\frac{I_c(s)}{I_e(s)} = -\frac{\alpha_N}{1 + s/\omega_\alpha} \quad (3)$$

[illegible]

$$\frac{V_e(s)}{I_e(s)} = \frac{r_e}{1 + sC_{se}r_e} + \frac{(1-\alpha_N)r_b}{1 + s/\omega_N}. \quad (4)$$

Fig. 5 shows ideal response to small signal rectangular pulses of current, $\Delta I$, and voltage, $\Delta V$, at the emitter.

For grounded emitter operation, the current gain and input impedance have their short circuit values if

$$\frac{R_c}{r_c} \ll 1 - \alpha_N \quad (5)$$ ✓

$$\omega_N C_c R_c \ll 1.$$

The current gain is

$$\frac{I_c(s)}{I_b(s)} = \frac{\alpha_0}{1 - \alpha_N + s/\omega_N}. \quad (6)$$

Input impedance is

$$\frac{V_b(s)}{I_b(s)} = r_b + \frac{r_e}{1 - \alpha_N + s/\omega_N}. \quad (7)$$

Fig. 6 shows ideal response to small-signal rectangular pulses of current, $\Delta I$, and voltage, $\Delta V$, to the base.

For grounded collector operation, the current gain has its short circuit value if

$$\frac{R_e}{r_c} \ll 1 - \alpha_N \quad (R_e = \text{load resistance in emitter circuit}) \quad (8)$$

$$\omega_N R_e C_c \ll 1.$$ ✓

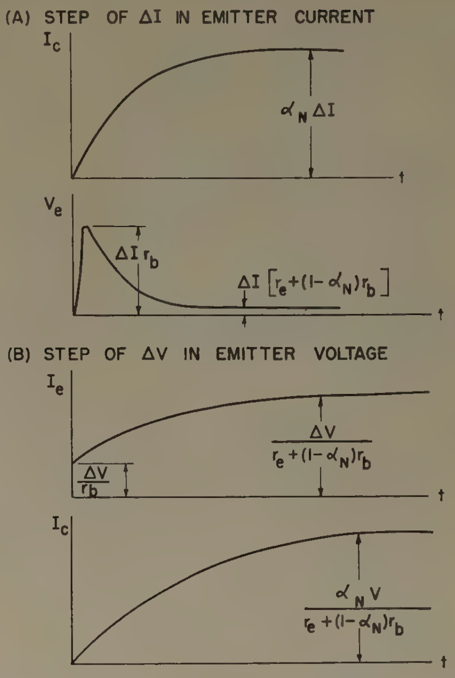

Fig. 5—Response of transistor in common base circuit to small signal steps (a) of $\Delta I$ in emitter current, and (b) of $\Delta V$ in emitter voltage. In (a) the time constant is $1/\omega_N$ and in (b) the time constant is

$$\frac{1}{\left(1 - \alpha_N + \frac{r_e}{r_b}\right)\omega_N}.$$

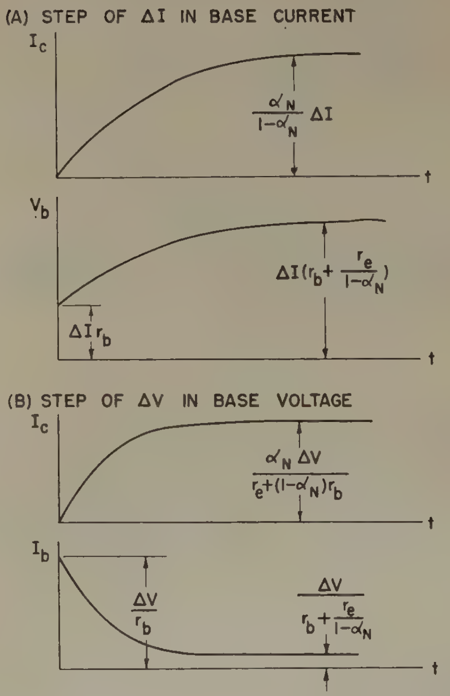

Fig. 6—Response of transistor in common emitter circuit to small signal steps (a) of $\Delta I$ in base current, and (b) of $\Delta V$ in base voltage. In (a) the time constant is $1/(1-\alpha_N)\omega_N$ and in (b) the time constant is

$$\frac{1}{\left(1 - \alpha_N + \frac{r_e}{r_b}\right)\omega_N}.$$

For this case,

$$\frac{I_e(s)}{I_b(s)} = \frac{1+s/\omega_N}{1-\alpha_N+s/\omega_N}. \qquad (9)$$

The input impedance under these conditions is

$$\frac{V_b(s)}{I_b(s)} = r_b + \frac{r_e+R_e(1+s/\omega_N)}{1-\alpha_N+s/\omega_N}. \qquad (10)$$

Fig. 7 shows ideal response of the grounded collector transistor to rectangular pulses of current $\Delta I$ and voltage $\Delta V$ to the base.

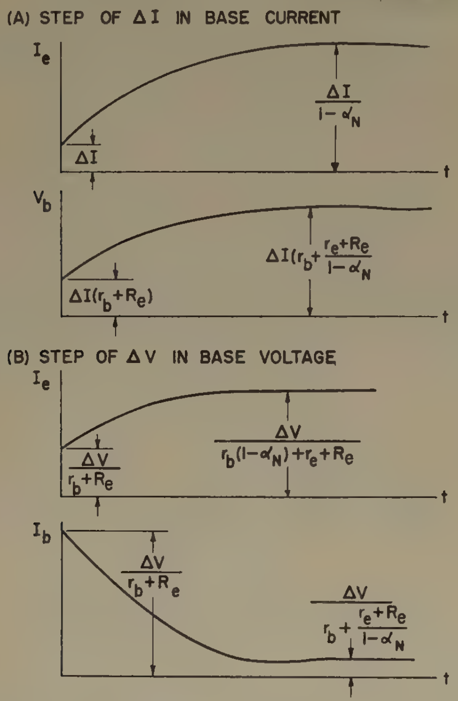

Fig. 7—Response of transistor in common collector circuit to small-signal steps of (a) $\Delta I$ in base current, and (b) of $\Delta V$ in base voltage. In (a) the time constant is $1/(1-\alpha_N)\omega_N$ and in (b) the time constant is

$$\frac{r_b+R_e}{r_e+R_e+r_b(1-\alpha_N)}\,\frac{1}{\omega_N}.$$

In general, if the conditions of (2), (5), and (8) are satisfied, the response time is not affected by the load resistance. However, if the load resistance is increased so that these conditions are not satisfied, the response time increases, and for large load resistance, is determined by the product of load resistance and collector capacitance.

### *Small-Signal Transient Behavior in the Current Saturation Region*

The formulation of the small-signal transient behavior in the current saturation region is a step in the calculation of storage time $T_1$. It is possible by means of some generalized considerations of relations between terminal currents and voltages to calculate storage time without resorting to specific solutions of the diffusion equation. This calculation of $T_1$ is based on the characterization of the transistor in the current saturation region and is carried out in a later section. Our immediate concern is to characterize the transistor in the current saturation region.

It has been shown[1] that the carrier density in the base layer, with voltages $\phi_E$ and $\phi_C$ respectively across the emitter and collector junctions, is the sum of two densities which are (for *n-p-n*)

$n_1 - n_p$ = excess carrier density which exists if the junction voltages are $\phi_E$ and 0. (11)

$n_2 - n_p$ = excess carrier density which exists if the junction voltages are 0 and $\phi_C$. (12)

This method of dividing the carrier density into two components is most useful in considering transistor operation in the current saturation region where both junctions are forward biased. In transistors with emitter and collector region of finite resistivity, there is also minority carrier storage in these regions. The minority carrier densities in the emitter and collector regions could be included without changing the results of the analysis, but would make the discussion more complex. The density in (11) is the result of emission from the emitter at voltage $\phi_E$, and collection at the collector at zero voltage. The density in (12) is the result of emission from the collector at voltage $\phi_C$, and collection at the emitter at zero voltage.

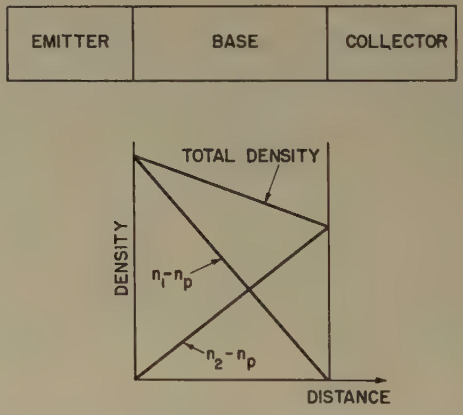

Fig. 8—Carrier density along a filament in the base layer while operating in the current saturation region. The density is divided into two components corresponding to normal $(n_1-n_p)$ and inverted $(n_2-n_p)$ operation.

The division of carrier density into two components is illustrated qualitatively in Fig. 8. This division of carrier density suggests the division of emitter and collector currents into two components which are associated with emission and collection. Thus (for *n-p-n*)

$$\begin{aligned} I_E &= -I_{Ef}+I_{Er} \\ I_C &= -I_{Cf}+I_{Cr}, \end{aligned} \qquad (13)$$

where $I_{Ef}$, $I_{Cf}$ = current due to emission from the emitter or collector and $I_{Er}$, $I_{Cr}$ = current due to collection at the emitter or collector. Since these two processes are independent, the usual current gain relations are

$$I_{cr}^{(s)} = + \frac{\alpha_N}{1 + \dfrac{s}{\omega_N}} I_{ef}(s), \tag{14}$$

where $\alpha_N$ and $\omega_N$ are the normal small-signal active region current gain and frequency cutoff, and

$$I_{er}^{(s)} = \frac{\alpha_I}{1 + \dfrac{s}{\omega_I}} I_{cf}^{(s)}, \tag{15}$$

where $\alpha_I$ and $\omega_I$ are the small-signal active region current gain and frequency cutoff which result if the transistor is inverted; i.e., the roles of the emitter and collector interchanged. This division of current into components has the desirable consequence of replacing a nonlinear phenomenon by two separate, essentially linear processes.

The frequency dependence of alpha assumed in (14) and (15) has not been justified for nonplanar geometry, but experience has shown that (14) and (15) are fairly good approximations.

The "theoretical" transistor is now completely characterized with the addition of voltage relations. (By the theoretical transistor is meant the transistor which neglects the voltage drop in the base layer.) The voltage relations are obtained from the forward or emitted current. Thus, with $\phi_C = 0$, the static relations are,

$$I_E = I_{Ef} = \frac{I_{E0}}{1 - \alpha_N \alpha_I} (e^{q\Phi_E/kT} - 1) \tag{16}$$

and with $\phi_E = 0$,

$$I_C = I_{Cf} = \frac{I_{C0}}{1 - \alpha_N \alpha_I} (e^{q\Phi_C/kT} - 1). \tag{17}$$

In (16) and (17), $\phi_E$ and $\phi_C$ are the actual voltages across the junctions. If $\phi_E$ and $\phi_C$ are simultaneously different from zero, the relations (16) and (17) continue to be valid for the emitted currents $I_{Ef}$ and $I_{Cf}$, but in this case the total emitter and collector currents differ from the emitted currents. For small-signal operation in the current saturation region, the small-signal emitter admittances must be used. Thus,

$$I_{Ef}(s) = Y_E(s)\phi_E(s) \tag{18}$$

$$I_{Cf}(s) = Y_C(s)\phi_C(s). \tag{19}$$

The admittances in (18 and (19) are

$$\begin{aligned} Y_E(s) &= \frac{I_{Ef}}{\dfrac{kT}{q}} + sC_{se} \\ Y_C(s) &= \frac{I_{Cf}}{\dfrac{kT}{q}} + sC_{sc}. \end{aligned} \tag{20}$$

It should be noted that the collector conductance $Y_C(s)$ in Region III is not the usual small-signal collector conductance, but is the conductance of a diode biased in the forward direction. The magnitude of the diffusion capacitances $C_{se}$ and $C_{sc}$ in (20) depends on emitter and collector current and geometry. However, the exact magnitudes of $C_{se}$ and $C_{sc}$ are only of secondary importance in determining switching-behavior. No attempt will be made here to evaluate these magnitudes. The resistive terms in (20) are accurate for any case.

Fig. 9 shows the small-signal equivalent circuit applicable to the current saturation region. For practical transistors resistances must be added to account for the spreading resistance in the base layer; hence the resistances, $r_1$ and $r_2$. This particular configuration of resistance is most nearly applicable to the transistor geometry, in which the emitter and collector junctions are planar but with larger diameter collector, as in Fig. 10.

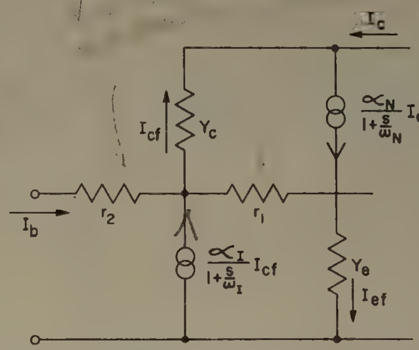
$I_C$
$I_{cf}$
$Y_C$
$\frac{\alpha_N}{1+\frac{s}{\omega_N}} I_{ef}$
$r_2$
$r_1$
$I_b$
$\frac{\alpha_I}{1+\frac{s}{\omega_I}} I_{cf}$
$Y_e$
$I_{ef}$

Fig. 9—Small-signal equivalent circuit for Region III with added base resistance.

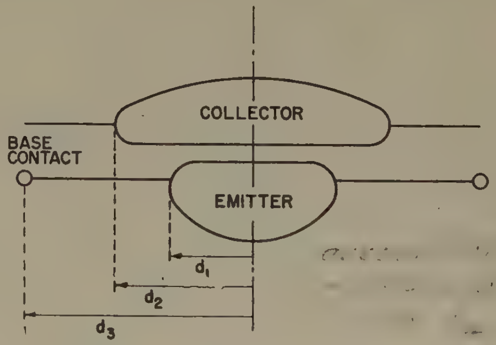

Fig. 10—Geometry of unsymmetrical transistor. The voltage drop from $d_1$ to $d_2$ results in $r_2$, and the voltage drop from $d_2$ to $d_3$ results in $r_1$.

At moderately high currents $r_1$ is the ohmic spreading resistance between the edge of the collector and the base contact, and $r_2$ is approximately the resistance between the edge of the emitter and the edge of the collector. Fig. 10 illustrates the physical regions which result in these resistances.

Many alloy or fused junction transistors have the unsymmetrical geometry shown in Fig. 10, with resulting unsymmetric electrical properties. In some switching applications it is advantageous that the transistor have symmetrical electrical properties; that is the electrical parameters in the inverted connection are the same as in the normal connection. (Transistors with symmetrical geometry clearly have symmetrical electrical properties.) Typical values of base spreading resistances for symmetrical transistors are about 100 Ω for $r_1$ and approximately zero for $r_2$. Typical values for a nonsymmetrical *n-p-n* transistor (0.015-inch diameter emitter, 0.030-inch diameter collector) are 20 Ω for $r_1$ and 100 Ω for $r_2$.

It has been observed in the common emitter circuit [Fig. 4(b)], that when the transistor operating point enters the current saturation region, the input resistance sometimes drops very rapidly to a small fraction of its active region value. The reason for this can be seen from the equivalent circuits of Figs. 3 and 9. The base resistance $r_b$ of Fig. 3 (active region) is approximately the sum of the resistances $r_1+r_2$ in Fig. 9 (current saturation). Hence, in the active range the input resistance to the circuit of Fig. 4(a) is very nearly $r_1+r_2$ at large currents where emitter resistance is negligible.

In the current saturation region, the load resistance is usually so large in comparison to the collector resistance (which may be a few ohms) that the transistor is effectively operating into an open circuit. Under these conditions the complex input impedance is (neglecting emitter resistance)

$$\frac{V_b(s)}{I_b(s)}=r_2+\frac{\left(1-\alpha_N+\frac{s}{\omega_N}\right)\left(1+\frac{s}{\omega_I}\right)r_1}{\frac{1}{\omega_N\omega_I}\left[s^2+s(\omega_N+\omega_I)+\omega_N\omega_I(1-\alpha_N\alpha_I)\right]}. \quad (21)$$

At low frequencies this reduces to

$$\left.\frac{V_b}{I_b}\right|_{s=0}=r_2+\frac{(1-\alpha_N)r_1}{1-\alpha_N\alpha_I}. \quad (22)$$

For the normal connection of the unsymmetric transistor, $1-\alpha_N \ll 1-\alpha_I$ and $r_2 \ll r_1$, so that the impedance in (22) may be much less than the active region base resistance. For symmetric transistors, however, $r_1$ is small and the impedance in (22) reduces to the active region base resistance. These calculations are in agreement with observations on symmetrical and nonsymmetrical transistors. At high frequencies, (21) becomes

$$\left.\frac{V_b}{I_b}\right|_{s=\infty}=r_1+r_2. \quad (23)$$

Eq. (23) gives the ratio of incremental voltage to incremental current immediately after the application of a step of current (or voltage) to the base circuit. In a time of the order of $1/\omega_N$ the ratio of incremental voltage to incremental current decays to the value given in (22). The effect of the frequency variation of the input impedance in (21) on switching-time is small. However, the above calculations explain the initial spike of voltage at the base terminal which is sometimes observed when a current pulse is applied to the base of unsymmetrical transistors in the common emitter circuit.

### *Large-Signal Switching-Times*

Large-signal switching-time is most conveniently discussed in terms of the three large-signal regions of operation which have been previously defined. For junction transistors the "high" current edge of the Region I (collector current cutoff) is at $I_C=I_{C0}$, and the "low" current boundary is at $I_C$ slightly less than $I_{C0}$. When calculating switching-times from collector current cutoff region to currents large compared to $I_{C0}$, no appreciable error is introduced if it is assumed that $I_{C0}=0$.

In Region II (active region) the switching-time is controlled by the small-signal active region parameters of the transistor. Since the equivalent impedances are strongly current dependent, exact large-signal transient response is sometimes quite difficult to calculate, but useful (and accurate) relations can be obtained.

In Region III (current saturation) both emitter and collector conductances are so small that the only remaining significant impedance is the base resistance (see Fig. 9). The static voltage drops in Region III are so small that it is reasonably accurate to assume that the entire supply voltage is across the external resistance in the circuit. Thus for a given load line the edge of Region III is at

$$I_C=\frac{V_{cc}}{R_c}. \quad (24)$$

Where

$V_{cc}$ = collector supply voltage

$I_C$ = current at edge of current saturation region.

Thus turn-on time from emitter cutoff to current saturation can be obtained from just a knowledge of the active region parameters. Turn-off time from current saturation to Region I (or Region II) requires knowledge of the transistor properties in the current saturation region.

In terms of the small-signal characterization of the transistor in the current saturation region, the transistor is in the current saturation region as long as the junction which normally functions as a collector is simultaneously collecting and emitting, and the junction which normally functions as an emitter is simultaneously emitting and collecting. In the active region, the collector is acting only as a collector and the emitter is acting only as an emitter. The transition of the operating point, from the current saturation region to the active region, consists in the decay of the emitted current from the collector, and the collected current from the emitter to zero. Storage time $T_1$ is the time required for these currents to decay to zero.

Turn-on time, $T_0$, will be calculated first, and then turn-off time considered in greater detail. Low-impedance load conditions are assumed for simplicity [see (2), (5), and (8)]. Turn-on time will be taken as the time required for the current to reach 90 per cent of its limiting value. Eqs. (3), (6), and (9) give the current transfer functions which apply to common base, emitter, and collector, and turn-on times may be calculated directly from these functions. The turn-on times from Region I to Region III for common base, emitter, and collector respectively are:

$$T_0 = \frac{1}{\omega_N} \ln \frac{I_E}{I_E - \dfrac{.9 I_C}{\alpha_N}} \quad \text{(common base)} \tag{25}$$

$I_E$ = emitter current after step is applied.
$I_C$ = collector current at edge of Region III.

$$T_0 = \frac{1}{(1-\alpha_N)\omega_N} \ln \frac{I_B}{I_B - .9\dfrac{1-\alpha_N}{\alpha_N} I_C} \quad \text{(common emitter)} \tag{26}$$

$I_B$ = base current after step is applied.
$I_C$ = collector current at edge of Region III.

$$T_0 = \frac{1}{(1-\alpha_N)\omega_N} \ln \frac{\alpha I_B}{I_B - .9(1-\alpha_N) I_E} \quad \text{(common collector)} \tag{27}$$

$I_E$ = emitter current at edge of Region III.
$I_B$ = base current after step is applied.

If the low impedance conditions of (2), (5), and (8) are not satisfied, the turn-on times are increased due to the time necessary to charge collector capacitance. If the transistor is not driven into saturation, (25), (26), and (27) still give the switching-time if $I_C$ or $I_E$ is taken as the asymptotic value in the active region.

To obtain turn-off times from the current saturation region, it will be assumed that carrier density has reached steady state, though this is not a necessary assumption. Calculations carried out in the Appendix I can be used to show that the carrier density reaches its steady-state value in a time

$$T_s \cong \left(\frac{1}{1-\alpha_I}\right)\omega_I,$$

where $T_s$ (see Fig. 2) is the time interval between the entrance of the operating point into Region III and the removal of the driving pulse. If

$$T_s \ll \frac{1}{(1-\alpha_I)\omega_I},$$

the storage time, $T_1$, is proportional to $T_s$. If

$$T_s > \frac{1}{(1-\alpha_I)\omega_I},$$

the carrier density has very nearly reached steady-state conditions and storage time is independent of the duration of the driving pulse. This is the case that will be considered here.

In terms of the equivalent circuit of Fig. 9, which applies to the current saturation region, the turn-off transient (for common base or emitter) may be described as follows:

The emitter (or base) current is reduced to a value corresponding to operation in Region I or II, or even to a reverse value. This results in an instantaneous reduction of the *forward* emitter current $I_{Ef}$ which in turn reduces the *collected* collector current. Since the collector conductance is small, there is no corresponding reduction of collector current or increase in collector voltage but, instead, there is a reduction of the *emitted* collector current. This process continues (reduction of emitted collector current) until the collector conductance becomes comparable to the external circuit resistance, at which time the collector voltage begins to increase. The decrease in collector conductance occurs at almost the same time as when the electron density associated with the emitted collector current vanishes. From this time on the turn-off transient is determined by the small-signal active region parameters of the transistor. The turn-off time is conveniently divided into two periods of time as follows:

$T_1$ = storage time = time interval between the reduction of control current and the entrance of the operating point into the active region.

$T_2$ = decay time = time required after the operating point has entered the active region for the collector current to decay to 10 per cent of its current saturation value.

For grounded collector operation, the turn-off begins when the step in current is applied to the base electrode. This immediately reduces the magnitude of the *emitted* collector current, which in turn reduces the collected emitter current and the emitted current from the emitter. The total emitter current remains essentially constant. This process continues as before until the operating point enters the active region.

Thus the definitions of storage time and decay time apply to all three types of operation, with $T_1$ being understood as the time to get out of current saturation (storage time), and $T_2$ the time to traverse the active region (decay time). As long as the transistor operating point is in the current saturation region, the transistor impedances are so low that it is most convenient to consider the currents as independent variables. In addition, the operation is nearly linear with respect to currents, but is very nonlinear with respect to voltage. A knowledge of the terminal currents $I_c$ and $I_e$ as a function of time, allows us to calculate the component currents $I_{cf}$, $I_{cr}$, $I_{ef}$, $I_{er}$ as a function of time. This calculation is carried out in Appendix I. It is found in general, during the turn-off transient, that $I_{cf}$ (current emitted from collector) reaches zero first and may actually reverse its direction for a short time. This reversal is possible because of diffusion capacitance (i.e. minority carrier storage) associated with current emitted from the collector.

When $I_{er}$ (current collected at the emitter) reaches zero, the electron density associated with emission from the collector has vanished, and the transistor is in the active region. In the active region, total emitter current is identical with the current emitted from the emitter, and the total collector current is identical with current collected at the collector (plus collector capacitance charging current). The time interval after the current emitted from the collector reaches zero and, before the current collected at the emitter reaches zero, is a dynamic transition period between the current saturation region and the active region. It is shown in Appendix I that in general,

$$T_1 = \frac{\omega_N + \omega_I}{\omega_N \omega_I (1 - \alpha_N \alpha_I)} \ln \frac{I_{E2} - I_{E1}}{\dfrac{I_{c1}}{\alpha_N} + I_{E2}} \text{ (common base)} \quad (28)$$

$$T_1 = \frac{\omega_N + \omega_I}{\omega_N \omega_I (1 - \alpha_N \alpha_I)} \ln \frac{I_{B1} - I_{B2}}{\dfrac{I_{C1}(1 - \alpha_N)}{\alpha_N} - I_{B2}} \text{ (common emitter)} \quad (29)$$

$$T_1 = \frac{\omega_N + \omega_I}{\omega_N \omega_I (1 - \alpha_N \alpha_I)} \ln \frac{I_{B2} - I_{B1}}{I_{B2} + I_{E1}(1 - \alpha_N)} \text{ (common collector).} \quad (30)$$

In these three equations, subscript 1 refers to values before the beginning of the turn-off, and subscript 2 refers to the values immediately after the beginning of the turn-off transient. At the end of the storage time, the load current is still very nearly its value in the current saturation region. (Usually 90 per cent or more). The slope of the load current transient is the value corresponding to active region circuit values. The decay time is obtained from the active region parameters. Only a small error is introduced by assuming that the current at the start of the decay time is the current saturation value of $I_{C1}$. The decay times to the 10 per cent points are

$$T_2 = \frac{1}{\omega_N} \ln \frac{I_{C1} + \alpha_N I_{B2}}{\dfrac{1}{10} I_{C1} + \alpha_N I_{B2}} \text{ (common base)} \quad (31)$$

$$T_2 = \frac{1}{(1 - \alpha_N)\omega_N} \ln \frac{I_{C1} - \dfrac{\alpha_N}{1 - \alpha_N} I_{B2}}{\dfrac{1}{10} I_{C1} - \dfrac{\alpha_N}{1 - \alpha_N} I_{B2}} \text{ (common emitter)} \quad (32)$$

$$T_2 = \frac{1}{(1 - \alpha_N)\omega_N} \ln \frac{I_{E1} - \dfrac{I_{B2}}{1 - \alpha_N}}{\dfrac{1}{10} I_{E1} - \dfrac{I_{B2}}{1 - \alpha_N}} \text{ (common collector).} \quad (33)$$

## EXPERIMENTAL RESULTS

It has been found that there is good agreement between actual small-signal transient behavior and the calculated behavior based on the equivalent circuit of Fig. 3. The biggest discrepancy is in rise times where there may be as much as ±20 per cent difference between calculated and measured values. This is probably due to the fact that $\omega_N$ as measured in the usual small signal ac circuit accounts only for amplitude changes in $\alpha_N$, while the phase dependence on frequency is also of importance in determining transient response.

The parameters to be used in the large-signal equations (25), (26), (27), and (28), (29), (30), (31), (32), (33) are obtained as follows:

$$\frac{\alpha_N}{1 - \alpha_N} = \text{ratio of dc base current/dc collector current at the edge of saturation.} \quad (34)$$

This method of measuring $\alpha_N$ results in an average value for $1-\alpha_N$. This is of importance only in determining how far into saturation the transistor is driven.

$$\frac{1}{(1 - \alpha_N)\omega_N} = \text{time constant for response to a pulse of base current.} \quad (35)$$

The parameters with inverse ($I$) subscripts are measured in the same way except that the emitter and collector are interchanged. In general $1-\alpha_I$ is relatively constant with operating point. The dependance of switching-time on the inverse characteristic occurs in (28), (29) and (30) in the coefficient

$$t = \frac{\omega_N + \omega_I}{\omega_N \omega_I (1 - \alpha_N \alpha_I)}. \quad (36)$$

It is found in general for unsymmetrical transistors that $\omega_N > \omega_I$ and $\alpha_N > \alpha_I$. For this case the magnitude of the coefficient in (36) is determined essentially by the product

$$\frac{1}{(1 - \alpha_I)\omega_I} = \text{time constant for response to a pulse of base current, inverted connection.} \quad (37)$$

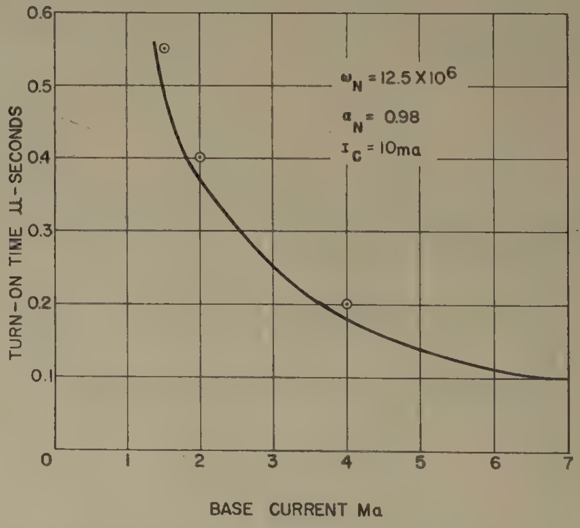

Fig. 11—Turn-on time as a function of driving current. The curve is calculated and the points are experimental.

Fig. 11, above, shows theoretical and experimental rise times for common emitter operation for an unsymmetrical transistor.[5] Fig. 12 (opposite page) shows theo-

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[5] An unsymmetrical transistor was chosen to present a more general case. Actually, the agreement between experiment and theory is as good or better for symmetrical transistors.

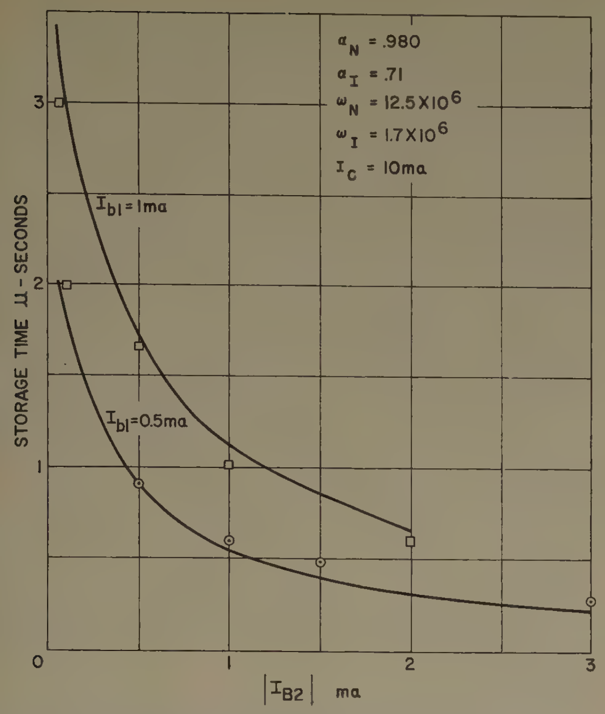

Fig. 12—Storage time as a function of turn-off drive. Curves are calculated and points are experimental.

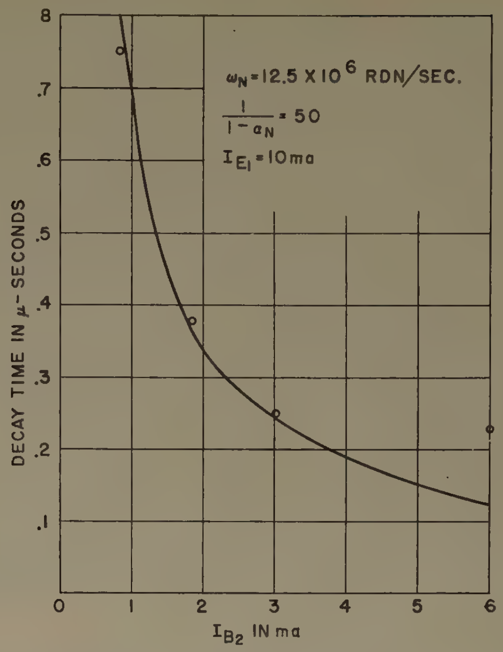

Fig. 13—Decay time as a function of turn-off drive. The curves are calculated and points are experimental.

retical and experimental values of storage time. The end of the storage time is measured as the time when the slope of the load current transient reaches its maximum value. For this particular transistor, the maximum slope in the load current transient occurred at about a 10 per cent decrease in the load current from its current saturation value. Fig. 13 shows theoretical and experimental values of decay times.

## Conclusions

The salient features of the active region transient response of junction transistors can be obtained from the simple equivalent circuit of Fig. 3.

The large signal switching-times, where the transistor operating point is changed from Region I (collector current cutoff) to Region III (collector current saturation), may be described in terms of three periods of time which are: $T_0$, the turn-on time, or time required for the load current to reach 90 per cent of its value in the current saturation region; $T_1$, the storage time, or time for the operating point to move from the current saturation region to the active region after the control current has been removed; and $T_2$, the decay time, or time for the load current to decay to 10 per cent of its saturation value after the operating point has entered the active region.

Formulas are given for $T_0$, $T_1$, and $T_2$, and experimental verification of the formulas are shown in Figs. 11, 12, and 13. It is useful to state these dependencies of switching times on circuit conditions in words. Thus, Fig. 11 shows that the greater the drive on the transistor, the faster it is turned on. For the common emitter connection, base currents of about $\frac{1}{5}$ the saturation value of the load current result in a turn-on time of approximately $3/\omega_N$. Fig. 12 shows that the further the transistor has been driven into current saturation, the longer it takes to get it out again. Also the greater the turn-off drive the faster it gets out of the current saturation region. Reverse (turn-off) currents in the base circuit of the order of $\frac{1}{5}$ the saturation value of the load current result in storage time of approximately $5/\omega_N$ to $10/\omega_N$. Fig. 13 shows that the greater the turn-off drive the shorter the decay time. Turn-off current of the order of $\frac{1}{5}$ the saturation value reduces the decay time to approximately $3/\omega_N$. Reduction of turn-on or turn-off time to $1/\omega_N$ requires drive current almost equal to the current saturation value of the load current.

These observations are, of course, in complete agreement with the intuitive picture of the transistor behavior. It has been assumed throughout that the load resistance was small enough that the effect of collector capacitance was negligible. If this is not the case the quantitative relations describing rise and fall times are changed, but the storage time is not affected. The qualitative observations above, concerning switching-time, are, of course, valid in any case.

The transient response of the transistor is not completely described unless the transient response of the input circuit is included. During the large-signal transient, the input impedances observed can be explained in terms of a slowly varying base resistance, and assuming emitter resistance to be very nearly zero. Thus the input impedance of the common emitter connection of the transistor is, for practical purposes, a resistance equal to base resistance during the transient.

It is significant that the emitter circuit remains a low impedance, even to reverse current during the turn-off part of the transient, until the collector current is almost zero. An exception to this rule is found where the reverse emitter current during turn-off is much larger than the collector current, as may be the case if voltages are being switched on and off, and switching speed is a prime requisite. In this case the emitter junction may recover first, and the qualitative behavior is changed somewhat. The emitter may also recover first even for moderate turn-off currents, if most of the carrier storage occurs in the collector region, as is the case in some grown junction transistors.

Large-signal transient behavior of junction transistors can be explained in terms of the familiar transmission parameters and the geometry of the device. The single most important parameter affecting switching speed is frequency cutoff of alpha. If both turn-on and turn-off times are of primary importance, a circuit technique which allows fairly large drive and which prevents the transistor from going into saturation will extend the range of application of existing devices.

## ACKNOWLEDGMENT

The author wishes to acknowledge the help of H. D. Young and H. Andrew in obtaining experimental data.

## APPENDIX I

It is the purpose of this Appendix to calculate the time of transition of the transistor operating point from the current saturation region to the active region. Under static conditions, the collector current at the transition between the active region and current saturation is $V_{cc}/R_c$, and the emitter current is $V_{cc}/\alpha_N R_c$. The emitted current from the collector is zero and the collected current at the emitter is zero. In the current saturation region, the emitter current is greater than $V_{cc}/\alpha_N R_c$ and carriers are being emitted from the collector and collected at the emitter. The transition from the current saturation region to the active region involves the decay of the emitted current, from the collector and collected current at the emitter to zero. When both of these currents have reached zero the transistor is in the active region.

Eqs. (13), (14), and (15) make possible the calculation of the four currents (38)

$I_{ef}$ = current emitted from emitter

$I_{er}$ = current collected at emitter

$I_{cf}$ = current emitted from collector (38)

$I_{cr}$ = current collected at collector

if the total emitter and collector currents are known as a function of time. As long as the transistor operating point is in the current saturation range, the emitter and collector currents are determined by external circuit conditions. Thus, during the first part of the turn-off transient, the emitter and collector current is known as a function of time. When the operating point is in the active region, the load current (collector current) is determined primarily by the active region parameters of the transistor and is relatively easy to calculate. The currents $I_{cf}$ and $I_{er}$ do not in general reach zero at the same time, so that there is a finite time during which a transition is taking place between the current saturation region and the active region. It is difficult to calculate the collector and emitter current exactly during this transition period, since the transistor parameters are changing quite rapidly. It is possible, however, to calculate the four currents $I_{ef}$, $I_{er}$, $I_{cf}$, $I_{cr}$ with reasonable accuracy, by assuming that the transistor has its current saturation characteristics (and hence collector and emitter currents) throughout the transition period. This makes possible the calculation of the beginning and end of the transition period, and hence the recovery time of the transistor. From (13), (14), and (15), the reverse emitter current is

$$I_{er} = -\alpha_I(s)\frac{I_C(s)+\alpha_N(s)I_E(s)}{1-\alpha_N(s)\alpha_I(s)} \tag{39}$$

and the forward collector current is

$$I_{cf} = -\frac{I_C(s)+\alpha_N(s)I_E(s)}{1-\alpha_N(s)\alpha_I(s)}. \tag{40}$$

Assume that before the turn-off step is applied that

$$\begin{aligned} I_e &= I_{E1} \\ I_c &= I_{C1} \\ I_b &= I_{B1} \end{aligned} \tag{41}$$

and that after the turn-off step

$$\begin{aligned} I_e &= I_{E2} \\ I_c &= I_{C2} \\ I_b &= I_{B2}. \end{aligned} \tag{42}$$

Then it follows that for incremental currents

$$\begin{aligned} I_E(s) &= \frac{I_{E2}-I_{E1}}{s} \\ I_C(s) &= \frac{I_{C2}-I_{C1}}{s} \end{aligned} \tag{43}$$

and

$$I_{Er}(s) = -\frac{\alpha_I(I_{C2}-I_{C1})\left(1+\frac{s}{\omega_N}\right)+\alpha_I\alpha_N(I_{E2}-I_{E1})}{\frac{s}{\omega_N\omega_I}\left(s^2+s(\omega_N+\omega_I)+\omega_N\omega_I(1-\alpha_N\alpha_I)\right)} \tag{44}$$

$$I_{cf}(s) = -\frac{(I_{C2} - I_{C1})\left(1 + \dfrac{s}{\omega_N}\right)\left(1 + \dfrac{s}{\omega_I}\right) + \alpha_N(I_{E2} - I_{E1})\left(1 + \dfrac{s}{\omega_N}\right)}{\dfrac{s}{\omega_N\omega_I}\left(s^2 + s(\omega_N + \omega_I) + \omega_N\omega_I(1 - \alpha_N\alpha_I)\right)}. \tag{45}$$

The inverse of (44) is (after restoration of dc values) ✓

$$\begin{aligned} I_{er} = -\frac{\alpha_I(I_{C2} + \alpha_N I_{E2})}{1 - \alpha_N\alpha_I} &+ \left[\frac{\alpha_I(I_{C2} - I_{C1})\left(\dfrac{\omega_B}{\omega_N} - \dfrac{\omega_B}{\omega_A}\right) - \dfrac{\omega_B}{\omega_A}\alpha_N\alpha_I(I_{E2} - I_{E1})}{(1 - \alpha_N\alpha_I)\left(1 - \dfrac{\omega_B}{\omega_A}\right)}\right] e^{-\omega_A t} \\ &+ \left[\frac{\alpha_I(I_{C2} - I_{C1})\left(1 - \dfrac{\omega_B}{\omega_N}\right) + \alpha_N\alpha_I(I_{E2} - I_{E1})}{(1 - \alpha_N\alpha_I)\left(1 - \dfrac{\omega_B}{\omega_A}\right)}\right] e^{-\omega_B t} \end{aligned} \tag{46}$$

where $\omega_A$ and $\omega_B$ are solutions of

$$\omega^2 - \omega(\omega_N + \omega_I) + \omega_N\omega_I(1 - \alpha_N\alpha_I) = 0. \tag{47}$$

The inverse of (45) is (dc values restored) ✓

$$\begin{aligned} I_{cf} = -\frac{I_{C2} + \alpha_N I_{E2}}{1 - \alpha_N\alpha_I} &+ \left[\frac{(I_{C2} - I_{C1})\left(\dfrac{\omega_B}{\omega_I} - \dfrac{\omega_B}{\omega_A}\right)\left(1 - \dfrac{\omega_A}{\omega_N}\right) + \alpha_N(I_{E2} - I_{E1})\left(\dfrac{\omega_B}{\omega_I} - \dfrac{\omega_B}{\omega_A}\right)}{(1 - \alpha_N\alpha_I)\left(1 - \dfrac{\omega_B}{\omega_A}\right)}\right] e^{-\omega_A t} \\ &+ \left[\frac{(I_{C2} - I_{C1})\left(1 - \dfrac{\omega_B}{\omega_N}\right)\left(1 - \dfrac{\omega_B}{\omega_I}\right) + \alpha_N(I_{E2} - I_{E1})\left(1 - \dfrac{\omega_B}{\omega_I}\right)}{(1 - \alpha_N\alpha_I)\left(1 - \dfrac{\omega_B}{\omega_A}\right)}\right] e^{-\omega_B t} \end{aligned} \tag{48}$$

where $\omega_A$ and $\omega_B$ are as before, and they can be approximated as

$$\begin{aligned} \omega_A &\cong \omega_N + \omega_I - \frac{\omega_N\omega_I(1 - \alpha_N\alpha_I)}{\omega_N + \omega_I} \\ \omega_B &\cong \frac{\omega_N\omega_I(1 - \alpha_N\alpha_I)}{\omega_N + \omega_I}. \end{aligned} \tag{49}$$

For nonsymmetric transistors, the alpha and frequency response of alpha are greater in one direction than the other. For definiteness call the direction of high alpha the normal direction. Then it is true in general that

$$\omega_B < \omega_I < \omega_N < \omega_A. \tag{50}$$

For common base or emitter, the beginning of the transition period from current saturation to active operation occurs at the solution of $I_{cf} = 0$ in (48). It is assumed that $I_{C2} = I_{C1}$.

$$t = t_{1C} \quad \text{when}$$

$$I_{cf} = 0$$

$$\frac{I_{C1} + \alpha_N I_{E2}}{\alpha_N(I_{E2} - I_{E1})} = \frac{\dfrac{\omega_B}{\omega_I} - \dfrac{\omega_B}{\omega_A}}{1 - \dfrac{\omega_B}{\omega_A}} e^{-\omega_A t_{1C}} + \frac{1 - \dfrac{\omega_B}{\omega_I}}{\dfrac{\omega_B}{\omega_A}} e^{-\omega_B t_{1C}}. \tag{51}$$

For common base or emitter, the end of the transition period is at

$$t = t_{1E} \quad \text{when}$$

$$I_{cf} = 0$$

$$\frac{I_{C1} + \alpha_N I_{E2}}{\alpha_N(I_{E2} - I_{E1})} = \frac{e^{-\omega_B t_{1E}}}{1 - \dfrac{\omega_B}{\omega_A}} - \frac{\omega_B/\omega_A}{1 - \dfrac{\omega_B}{\omega_A}} e^{-\omega_A t_{1E}}. \tag{52}$$

With the relative values of frequencies in (50), it is true that

$$0 < t_{1C} < t_{1E}. \tag{53}$$

If

$$\frac{\omega_I}{\omega_N}(1-\alpha_N\alpha_I) < 1/10, \tag{54}$$

then the end of the transition is very nearly at

$$T_1 = \frac{\omega_N+\omega_I}{\omega_N\omega_I(1-\alpha_N\alpha_I)} \ln \frac{I_{E2}-I_{E1}}{I_{E2}+\dfrac{I_{C1}}{\alpha}} \tag{55}$$

$$= \text{storage time.}$$

In terms of base current, (55) is

$$T_1 = \frac{\omega_N+\omega_I}{\omega_N\omega_I(1-\alpha_N\alpha_I)} \ln \frac{I_{b1}-I_{b2}}{\dfrac{I_{C1}(1-\alpha_N)}{\alpha_N}-I_{b2}} \cdot \tag{56}$$

For the common collector connection $I_{E2}=I_{E1}$ and $I_{C2}-I_{C1}=I_{B1}-I_{b2}$. In this case the beginning of the transition ($t_{1C}$) is determined from the equation

$$\frac{I_{B2}+(1-\alpha_N)I_{E1}}{I_{B2}-I_{B1}} = \frac{\left(1-\dfrac{\omega_B}{\omega_N}\right)\left(1-\dfrac{\omega_B}{\omega_I}\right)}{1-\dfrac{\omega_B}{\omega_A}} e^{-\omega_B t_{1C}}$$

$$+ \frac{\left(\dfrac{\omega_B}{\omega_I}-\dfrac{\omega_B}{\omega_A}\right)\left(1-\dfrac{\omega_A}{\omega_N}\right)}{1-\dfrac{\omega_B}{\omega_A}} e^{-\omega_A t_{1C}}. \tag{57}$$

The end of the transition ($t_{1E}$) is determined from

$$\frac{I_{B2}+(1-\alpha_N)I_{E1}}{I_{B2}-I_{B1}} = \frac{1-\dfrac{\omega_B}{\omega_N}}{1-\dfrac{\omega_B}{\omega_A}} e^{-\omega_B t_{1E}}$$

$$+ \frac{\dfrac{\omega_B}{\omega_N}-\dfrac{\omega_B}{\omega_A}}{1-\dfrac{\omega_B}{\omega_A}} e^{-\omega_A t_{1E}}. \tag{58}$$

For the condition of (54), this reduces to

$$t_{1E} = \frac{\omega_N+\omega_I}{\omega_N\omega_I(1-\alpha_N\alpha_I)} \ln \frac{I_{B2}-I_{B1}}{I_{B2}+(1-\alpha_N)I_{E1}} \tag{59}$$

$$= \text{storage time.}$$

It can easily be shown that as $1-\alpha_N\alpha_I \to 0$, the start and end of the transition period approach each other.

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# Criteria for the Amplitude Stability of a Power Oscillator*

WILLIAM R. MacLEAN†, ASSOCIATE, IRE

*Summary*—**Criteria for the amplitude stability of a power oscillator are derived in the form of two inequalities. These inequalities involve derivatives which are computed graphically from the constant current design diagram that is customarily used for power oscillators. In the final form of the inequalities, the derivatives used are of the double logarithmic type: that is the fractional increment of one variable divided by the fractional increment of the other. In addition, the criteria involve the ratio of fed-back power to plate power and the ratio of the time constant of the grid leak and condenser combination to the time constant of the tank circuit. There are also involved certain trigonometric functions of the grid current and plate current angles of flow.**

## INTRODUCTION

IT WAS long ago observed that conventional vacuum tube oscillators sometime exhibit the phenomenon of blocking or intermittent operation.[1] This kind of self modulation, known also as amplitude instability or squegging, is most noticeable in the case of power oscillators, that is, oscillators in which the plate tank $Q$ is low and the feedback coupling is strong. For work in pulsing circuits, the phenomenon has been carried to an extreme by the development of the circuit known as the blocking oscillator. The criteria here developed do not pertain to the blocking oscillator *per se*, that is, to the one which is made to block on purpose and which exhibits a highly non-sinusoidal wave form, but pertain rather to oscillators which block accidentally. The criteria give threshold conditions where blocking or amplitude instability just barely begins.

The development takes into account the essential nonlinearities of a vacuum tube power oscillator. In particular, the nonlinear phenomenon of grid current is handled as such. The development is carried out for a tuned plate oscillator and is subject to certain limiting assumptions which will become apparent in the course of the discussion.

The discussion takes its departure from Fig. 1 (following page). The diagram is mostly self-explanatory. However, it is assumed—and that constitutes one of the limiting assumptions—that the coupling between the plate and grid coil is perfect. This implies that the dynamic grid voltage is proportional to the dynamic plate voltage. The proportionality constant is $\rho$, as shown on the diagram.

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* Original manuscript received by the I.R.E., April 7, 1954; revised manuscript received, Sept. 16, 1954. Presented at the "Symposium on Nonlinear Circuit Analysis," Polytechnic Institute of Brooklyn, April 23–24, 1953.

† Polytechnic Institute of Brooklyn, N. Y.

[1] R. T. Beatty and A. Gilmour, *Phil. Mag.*, vol. 40, pp. 291–295; September, 1920.

In Fig. 1, the parallel tank resistor, $R_T$, is presumed to include all of the reflected loads to the plate tank from any secondary coils that may be coupled to the tank. This tank resistor does not, however, include the effective load that is reflected by the grid leak or by the grid current itself.

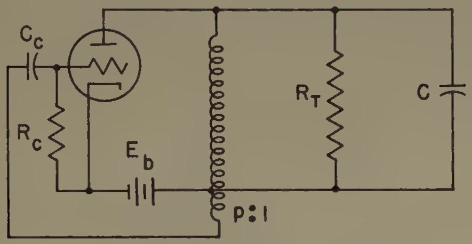

Fig. 1—Circuit diagram of oscillator.

The investigation of amplitude stability begins with a presumed design of the oscillator, yielding certain critical values for some of the circuit parameters and for some of the voltages and currents involved. The original design is then analyzed for the question of stability. The voltages and currents predicted or derived from the original design are called the steady state values. The circuit is then presumed to operate in the neighborhood of these steady state values and the dynamics of the system are examined to determine whether small deviations grow, which would indicate instability. Instability does not necessarily mean periodic blocking. It is conceivable that the design values may be impossible, though stable oscillatory conditions establish themselves elsewhere.

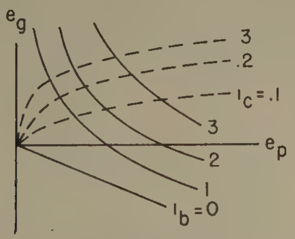

Fig. 2—Constant current design curves in the voltages plane.

## STEADY STATE

Before proceeding, it is necessary to summarize the results of the steady state design. The method used is that of Mouromtseff and Kozanowski.[2] This design proceeds from the constant current curves, as shown in Fig. 2. If now it is assumed that the plate circuit tank has a sufficiently high $Q$ to insure that the dynamic plate voltage is nearly sinusoidal, then the dynamic grid voltage will also be nearly sinusoidal and will swing in phase opposition to the plate voltage, so that the locus of the operating point in the plate voltage-grid voltage plane of the constant current diagram will be a straight line. In Fig. 3, this diagram is again repeated with fewer of the constant current curves on it, but with half of this straight line shown. This line is usually called the swing line, and indicates how the operating point in the plate voltage-grid voltage plane swings during the cycle. For convenience, we assume Class C operation, though it is not absolutely essential. In the case of Class C operation, the plate current does not flow on half the cycle, so it is not necessary to draw the other half of the swing line on the diagram. The swing line as shown in Fig. 3 should indicate completely the operation of the circuit.

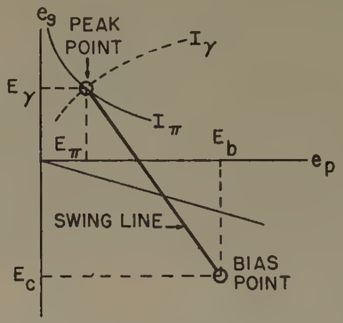

Fig. 3—Voltages plane design diagram showing swing line.

The position of the swing line in the voltages plane depends upon four parameters, namely, the two coordinates of its two ends. One end is called the *bias point* and has coordinates equal to the grid bias and the plate battery. The other end, called the *peak point*, has coordinates which are the peak grid voltage and the minimum plate voltage. One sees immediately from this diagram of Fig. 3 that the Class C oscillator has just four degrees of freedom of adjustment. As can be seen from Fig. 3, the maximum or peak value of grid voltage is designated by $E_\gamma$, and the minimum value of plate voltage is indicated by $E_\pi$. These are the co-ordinates of the peak point. From the voltages indicated in Fig. 3, certain other voltages can be immediately calculated. For instance, the horizontal projection of the swing line is equal to the fundamental component of plate voltage, $E_p$. This is indicated in (1) below. An expression for the fundamental component of grid voltage is also given.

$$\begin{aligned} E_p &= E_b - E_\pi \\ E_g &= E_\gamma - E_c. \end{aligned} \tag{1}$$

Fig. 3 also shows the cutoff or zero plate current line sloping downward to the right. The slope of this cutoff line is $-\mu^{-1}$, where $\mu$ is the amplification factor of the tube. When the operating point moving on the swing line crosses this cutoff line, plate current begins to flow. When it crosses the horizontal axis, grid current begins to flow. At the peak point certain values of grid and plate current have been attained, which are indicated on the diagram by $I_\gamma$ and $I_\pi$.

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[2] I. E. Mouromtseff and H. N. Kozanowski, PROC. I.R.E., pp. 752–778; July, 1935.

From the geometry of Fig. 3, the angles of flow for the grid and plate currents have to be calculated. For this purpose certain geometrical aspects of Fig. 3 are redrawn in Fig. 4. In this latter figure, the swing line is shown dotted where no current flows; is shown of medium width where only plate current flows; and is shown heavy where both plate and grid currents flow.

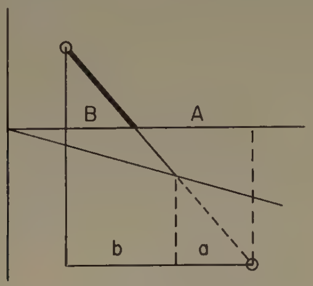

Fig. 4—Design diagram with swing line emphasized where currents flow.

On this diagram certain intercepts are labeled $a$, $b$ and $A$, $B$. These may be read as volts or may simply be read as inches, since only their ratios will be used. From these four letters the plate and grid half angles of flow, $\theta_p$ and $\theta_g$, may be calculated:

$$\cos\theta_p = \frac{a}{a+b}$$
$$\cos\theta_g = \frac{A}{A+B}. \tag{2}$$

During oscillation, grid current and plate current flow in pulses as indicated in Fig. 5. The pulses indicated there can be resolved by Fourier analysis into their dc and fundamental components. If we call these $I_b$, $I_c$ and $I_p$, $I_g$, respectively, then we may write:

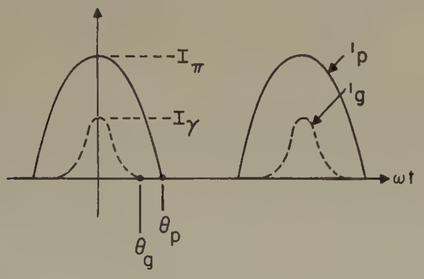

Fig. 5—Grid and plate current wave shapes.

$$I_p = \phi_p I_\pi, \qquad I_g = \phi_g I_\gamma$$
$$I_b = \phi_b I_\pi, \qquad I_c = \phi_c I_\gamma. \tag{3}$$

Since in (3) all the capital $I$'s have been specified, these equations serve as the implicit definition of the $\phi$'s shown therein. The $\phi$'s are the ratios between the dc and fundamental currents and the peak values of these currents. The values of the $\phi$'s depend upon the wave shapes of the plate current and grid current pulses. If certain geometrical forms for these pulses are assumed, then the values of the $\phi$'s can be calculated.

It is convenient to note that:

$$\rho = \frac{E_g}{E_p}. \tag{4}$$

The value of the grid leak, $R_c$, can be calculated from the quantities already mentioned. It is just given by:

$$R_c = \frac{-E_c}{I_c}. \tag{5}$$

An equivalent driving resistance, $R_g$, can be specified as the ratio of the fundamental component of grid voltage to the fundamental component of grid current. This is shown in (6):

$$R_d = \frac{E_g}{I_g} \text{ (a nonlinear resistance).} \tag{6}$$

Such "linearization" of an essentially nonlinear quantity has been much discussed in the literature.[3,4]

In the circuit shown in Fig. 1, the grid leak, $R_d$, is subjected to radio frequency voltage and has flowing in it radio frequency currents. This could be prevented by putting a radio frequency choke in series with it. If this is not done, the grid leak appears directly as reflected loading in the tank circuit. In case no radio frequency choke is used, it is convenient to define a new resistance, $R_0$, which includes the reflected value of the grid leak. This would be calculated immediately from the relation:

$$\frac{1}{R_0} = \frac{1}{R_T} + \frac{\rho^2}{R_c}. \tag{7}$$

In the following it is to be understood that $R_T$ is to be used in place of $R_0$, in case there is a radio frequency choke in series with the grid leak, or also in case the grid leak is connected across the grid condenser instead of from grid to cathode as shown in Fig. 1.

It is also convenient to define a new resistance, $R_L$, as the parallel combination of $R_0$ and the equivalent reflected resistance due to grid driving power. This relation would be:

$$\frac{1}{R_L} = \frac{1}{R_0} + \frac{\rho^2}{R_d} = \frac{E_p}{I_p}. \tag{8}$$

The resistance, $R_L$, represents the total effective load on the plate of the tube, as indicated in (8). This resistance, $R_L$, which represents the load resistance, is not a linear resistance. The component $R_0$ is linear, but $R_d$, the equivalent driving resistance, is nonlinear.

It is also convenient to define some of the powers involved: for instance, the total power output from the plate of the tube, $P_L$, and the total power required to drive the grid, $P_d$. Expressions for these would be:

$$P_d = \tfrac{1}{2}E_g I_g \quad \text{and} \quad P_L = \tfrac{1}{2}E_p I_p. \tag{9}$$

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[3] F. B. Llewellyn, *Bell. Sys. Tech. Jour.*, pp. 433–462; July, 1926; and PROC. I.R.E., pp. 2063–2094; December, 1931.

[4] E. Peterson, *Trans. A.I.E.E.*, pp. 528–534; May, 1927.

In addition to the voltage feedback ratio, $\rho$, use can be made of the power feedback ratio, $\delta$. This is expressed by:

$$\delta = \frac{P_d}{P_L}. \tag{10}$$

## DYNAMICS OF SELF-MODULATION

Up to this point, the discussion has been a review of the standard, general, constant current design procedure. It is assumed that such a design has been carried out and that values for the plate battery and feedback ratio have been decided upon. It is assumed that the swing line has then been placed on paper in the design position and the values of the relevant currents and voltages observed and/or calculated, that from these the necessary tank load resistance, $R_T$, yielding the requisite $R_L$ has been determined, and that the grid leak value, $R_C$, has been determined also. The voltages and currents calculated in this manner are now considered the design center or steady state values, which may be modulated by fluctuation increments.

The idea of investigating fluctuations around a design center has been the method always used to attack the stability problem, and various results have been obtained.[5,6]

Of the intrinsic four degrees of freedom mentioned earlier, two are definitely fixed: the value of the plate battery will not be changed by fluctuations, nor will the value of the feedback ratio. In terms of the swing line shown in Fig. 3, this means that the horizontal co-ordinate of the bias point is definitely fixed, and so is the slope of the swing line. Any flutter in the operating condition could cause the length of the swing line and the vertical co-ordinate of the bias point to change—the latter by changing the grid current, and hence the dc grid bias, which is automatically determined by the grid current and the grid leak resistor. The possible instability has, therefore, two degrees of freedom. These degrees of freedom are shown diagrammatically in Fig. 6, which is again a repetition of the grid voltage-plate voltage plane. Fig. 6 shows an original swing line as a solid line, and a possible modified swing line as a dotted line. To designate the change, the increase in grid bias and the increase in plate voltage swing are indicated by the two letters, $F_c$ and $F_p$. In case of amplitude instability, these two letters would become two dynamical variables varying with frequency components presumed to be far less than the fundamental frequency on the oscillator.

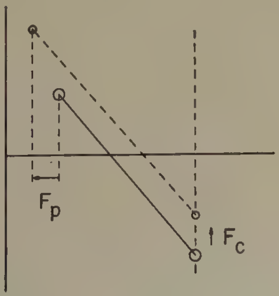

Fig. 6—Diagram showing the two remaining degrees of freedom.

The approach to the problem of stability herein used, is to seek two differential equations relating in a dynamical way to these two variables. An examination of these differential equations can then subsequently give information concerning stability. From this point on, the design center or steady state values of voltages and currents will carry the additional subscript zero. The same letters without the additional subscript will represent the instantaneous values. In (11),

$$\begin{aligned} E_c &= E_{c0} + F_c, \\ E_p &= E_{p0} + F_p, \end{aligned} \tag{11}$$

is given the expression relating the instantaneous value of the grid bias voltage, $E_c$, with the design center value, $E_{c0}$, and the fluctuation in bias, $F_c$. Eq. 11 also gives the relationship between the instantaneous phasor amplitude of fundamental plate voltage, $E_p$, and the design center value and fluctuation increment, $F_p$.

A generic instantaneous current $I$ is related to a design center value by:

$$I = I_0 + J. \tag{12}$$

The fluctuating component in any current is designated by $J$, as shown in (12). Since the fluctuations in the currents must depend on the two fluctuations in the voltages, these are related together by certain derivatives. For convenience, six such derivatives are tabulated:

$$\begin{aligned} S_p &= \frac{\partial I_p}{\partial E_p}, & B_p &= \frac{\partial I_p}{\partial E_c} \\ S_c &= \frac{\partial I_c}{\partial E_p}, & B_c &= \frac{\partial I_c}{\partial E_c} \\ S_g &= \frac{\partial I_g}{\partial E_p}, & B_g &= \frac{\partial I_g}{\partial E_c}. \end{aligned} \tag{13}$$

To facilitate remembering the significance of the letters $S$ and $B$ in (13), it might be remarked that $S$ stands for swing and $B$ stands for bias. Hence $S_p$ is the partial derivative of fundamental plate current with respect to fundamental plate voltage, i.e. to swing. Based upon these six derivatives, the relevant fluctuating currents are:

$$\begin{aligned} J_p &= S_pF_p + B_pF_c \\ J_c &= S_cF_p + B_cF_c \\ J_g &= S_gF_p + B_gF_c. \end{aligned} \tag{14}$$

Equations (14) are seen to derive readily from the fundamental ideas of calculus.

It is now necessary to seek certain differential equations in the fluctuation quantities. For instance, if there

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[5] J. van Slooten, *Wireless Eng.*, vol. 16, pp. 16–19; January, 1939; and *Phillips Tech. Rev.*, vol. 7, pp. 40–45; February, 1942.

[6] A. S. Gladwin, *Wireless Eng.*, vol. 26, pp. 159–170; May, 1949.

is a fluctuation in the dc grid current, the bias will not remain stationary. Fig. 7 shows a fragmentary diagram in which the currents flowing in and out of the condenser are labeled. It is obvious from Fig. 7, that differential equation (15) holds.

$$-\dot{F}_c = \frac{1}{C_c}\left(J_c + \frac{F_c}{R_c}\right). \tag{15}$$

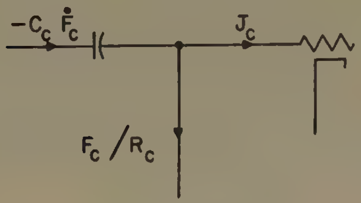

Fig. 7—Circuit diagram showing grid condenser charging.

This is one of the differential equations. There must, however, be two. A second one is derived from considerations of energy balance in the tank circuit. This cannot be readily shown by currents flowing on a diagram, but may be calculated analytically.

In (16), the time derivative of the total stored energy in the plate tank circuit is equated to the difference between the power that is fed into the tank circuit and the power that is delivered by the tank circuit to the various loads.

$$\frac{d}{dt}\left(\frac{1}{2}\,CE_p{}^2\right) = \frac{1}{2}\,E_pI_p - \frac{1}{2}\,\frac{E_p{}^2}{R_0} - \frac{1}{2}\,E_gI_g. \tag{16}$$

In the steady state condition, the time derivative in (16) is zero, as is shown in (17):

$$0 = \frac{1}{2}\,E_{p0}I_{p0} - \frac{1}{2}\,\frac{E_{p0}{}^2}{R_0} - \frac{1}{2}\,E_{g0}I_{g0}. \tag{17}$$

By carrying out the differentiation indicated in (16), by inserting on the right-hand side expressions for the instantaneous voltages in terms of the design center values and the fluctuations, and by use of (17), a differential equation in the fluctuation values is obtained.

$$\begin{gathered} 2C\dot{F}_p + \left(\frac{1}{R_0} - S_p + \rho S_g\right)F_p - (B_p - \rho B_g)F_c = 0 \\ S_cF_p + C_c\dot{F}_c + \left(\frac{1}{R_c} + B_c\right)F_c = 0. \end{gathered} \tag{18}$$

This equation is given as the first one of the group (18), in which group (15) is also repeated in slightly different form. Equations (18) are two differential equations for the determination of the two dynamical variables $F_p$ and $F_c$. These are seen to be linear equations with constant coefficients and hence the solution is easy. As shown generically in (19),

$$F = \operatorname{Re} \overline{F}\epsilon^{ht}, \tag{19}$$

the assumption is now made that the time variation of the $F$'s is exponential. This is the standard method of solving differential equations with constant coefficients. By substituting (19) into (18), a set of linear equations for the $\overline{F}$'s is obtained. Since these equations are homogeneous, solutions exist only when the determinant of the coefficients is zero. In place of each derivative there now appears the factor $h$. A solution therefore exists only when the determinant shown below is zero.

$$\begin{vmatrix} \left[2Ch+\rho S_g+\dfrac{1}{R_0}-S_p\right] & [\rho B_g-B_p] \\ [sc] & \left[C_ch+\dfrac{1}{R_c}+B_c\right] \end{vmatrix} = 0. \tag{20}$$

Eq. (20) is a quadratic expression for $h$. If the roots of (20) lie entirely in the left-hand half of the complex plane, then in (18) the $F$'s will be damped out. The criterion for stability is simply that the real part of $h$ be negative. To present this requirement in a more compact form, it is convenient to introduce certain abbreviations. One such is the time constant, $T_c$, of the grid leak and condenser combination. Another such is the time constant, $T_L$, of the tank circuit. Expressions for these are shown in (21):

$$T_c = R_cC_c, \qquad T_L = 2R_LC. \tag{21}$$

The expressions for the criteria become somewhat more compact if use is made of the simple relationship shown in (22):

$$\frac{R_L}{R_0} = 1 - \delta. \tag{22}$$

This simple equation can readily be proved from the definition of $\delta$.

The quadratic equation (20) for $h$ contains the derivatives $S$ and $B$. It is more convenient to introduce the double logarithmic derivatives $\sigma$ and $\beta$ shown in (23):

$$\begin{aligned} \sigma_p &= \frac{E_p}{I_p}\,S_p, & \beta_p &= \frac{-E_c}{I_p}\,B_p \\ \sigma_c &= \frac{E_p}{I_c}\,S_c, & \beta_c &= \frac{-E_c}{I_c}\,B_c \\ \sigma_g &= \frac{E_p}{I_g}\,S_g, & \beta_g &= \frac{-E_c}{I_g}\,B_g. \end{aligned} \tag{23}$$

$S_p$, for instance, is the derivative of the fundamental plate current with respect to the fundamental plate voltage swing while $\sigma_p$ is the fractional increment of the fundamental plate current divided by the fractional increment of the fundamental plate voltage swing. It is therefore the double logarithmic derivative. By means of (23), the coefficients of the quadratic equation (20) for $h$ are re-calculated in terms of $\sigma$ and $\beta$, instead of in terms of $S$ and $B$.

This quadratic equation is then examined to determine the conditions necessary in order that the roots lie in the left-hand half of the complex plane.

A cursory examination of (20) shows that the leading coefficient, i.e., that of $h^2$ is positive. In this case, it can readily be shown that the necessary and sufficient condition for the roots to lie in the left hand half of the complex plane is simply that the other two coefficients also be positive.

If the details are carried through and the quantities introduced in (21), (22), and (23) are used, the coefficients must be as shown in (24):

$$\begin{aligned} &(1+\beta_c)+\frac{T_c}{T_L}(1-\delta+\delta\sigma_g-\sigma_p)>0 \\ &(1+\beta_c)(1-\delta+\delta\sigma_g-\sigma_p)+\sigma_c(\beta_p-\delta\beta_g)>0. \end{aligned} \tag{24}$$

The criteria given in (24) are correct within the framework of the assumptions made so far. They have been derived by known "old methods"[7] of applied mathematics. Engineering requirements, however, demand not just theoretically correct mathematical answers, but mathematical answers that are simple enough to be serviceable. This is done chiefly by adopting all tolerable simplifying approximations. Each such approximation improves the serviceability of a formula, but diminishes its accuracy. The art lies in knowing about how far to simplify, as well as in choosing a good presentation of the final formula.

I do not feel that the criteria in (24) are simple enough to be serviceable. A much simpler and more useful set of criteria may be obtained if certain additional simplifying approximations are made. This will now be done.

## CRITERIA FOR STABILITY

Referring to Fig. 5, it is now assumed that the plate current wave is the top of a sinusoid and that the grid current wave is triangular. It is further assumed that the half angle of grid current flow is small. These conditions are summarized in (25).

$$\begin{aligned} i_p&: \text{ top of sinusoid} \\ i_g&: \text{ triangular} \\ \theta_g&: \text{ small.} \end{aligned} \tag{25}$$

These assumptions concern the shape of the current waves at the design center point, i.e., the point of normal operation. Anyone familiar with the appearance of these wave shapes knows that such an approximation, although not by any means exact, does not do violence to the general trends.[8] Far off the normal operating point, however, the plate current curve can have a double hump—but the stability criteria are not intended for use there.

The assumption that $i_p$ is sinusoidal, immediately allows the calculation of the factor $\phi_p$ relating the peak value of plate current with the fundamental value. This formula is well known and can readily be calculated to be as shown here in (26):

$$\begin{aligned} \phi_p &= \frac{1}{2\pi}\,\frac{2\theta_p-\sin 2\theta_p}{1-\cos\theta_p} \\ \phi_c &= \frac{1}{2}\,\phi_g=\frac{\theta_g}{2\pi}\,. \end{aligned} \tag{26}$$

Also, as a result of the assumptions about grid current, one can readily prove that the two factors $\phi_c$ and $\phi_g$ are related as shown in (26), and that their values are as given there.

The essential difficulty with the criteria given in (24) is that the values of the $\sigma$'s and $\beta$'s cannot be read immediately from the constant current diagram. $\sigma_p$, for instance, is the fractional increment of the fundamental component of plate current divided by the fractional increment in the fundamental component of plate voltage. The latter can be indicated on the diagram but the former cannot. What can be read directly from the diagram is the increment in the value of the peak plate current.

In line with this thought, it is convenient to introduce a new set of $\sigma$'s and $\beta$'s, which are subscripted $\pi$ and $\gamma$ rather than $p$, $c$, and $g$. These are the double logarithmic derivatives relating the corresponding peak currents with the respective voltages. The derivative of the fundamental plate current is related to that of the peak value by an equation which also involves the derivative of the $\phi$ factor. The exact relationship can readily be shown to be as in the first line of (27):

$$\begin{aligned} \sigma_p &= \sigma_\pi+\frac{\phi_p'}{\phi_p}\,E_p\,\frac{\partial\theta_p}{\partial E_p}, & \beta_p &= \beta_\pi+\frac{\phi_p'}{\phi_p}\,(-E_c)\,\frac{\partial\theta_p}{\partial E_c} \\ \sigma_c &= \sigma_\gamma+\frac{\phi_c'}{\phi_c}\,E_p\,\frac{\partial\theta_g}{\partial E_p}, & \beta_c &= \beta_\gamma+\frac{\phi_c'}{\phi_c}\,(-E_c)\,\frac{\partial\theta_g}{\partial E_c} \\ \sigma_g &= \sigma_\gamma+\frac{\phi_g'}{\phi_g}\,E_p\,\frac{\partial\theta_g}{\partial E_p}, & \beta_g &= \beta_\gamma+\frac{\phi_g'}{\phi_g}\,(-E_c)\,\frac{\partial\theta_g}{\partial E_c}\,. \end{aligned} \tag{27}$$

Eq. (27) gives the complete set of relationships between the $\sigma$'s and $\beta$'s subscripted by $p$, $c$, and $g$ and the $\sigma$'s and $\beta$'s subscripted $\pi$ and $\gamma$. These latter can be read directly from the constant current diagram by making an arbitrary small shift in the swing line. A further simplification comes about by virtue of the relationship shown as the second equation of (26). This together with (27) gives as a result:

$$\begin{aligned} \sigma_g &= \sigma_c \\ \beta_g &= \beta_c. \end{aligned} \tag{28}$$

To apply (27), the logarithmic derivatives of the $\phi$ factors are required. For $\phi_c$ and $\phi_g$ these derive very simply, but for $\phi_p$ the calculation is a little more complicated. It is convenient therefore, to designate the logarithmic derivative of $\phi_p$ simply as $\psi$.

$$\psi(\theta_p)=\frac{\phi_p'}{\phi_p}\,. \tag{29}$$

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[7] N. Minorsky, "Non-linear Mechanics," Edwards Bros., Inc., Ann Arbor, Mich. *Foreword*; 1947.

[8] W. G. Wagener. "Simplified methods for computing performance of transmitting tubes," PROC. I.R.E., vol. 25, pp. 47–77; January, 1937.

This function of the plate half angle of flow is given specifically in (30):

$$\psi = \sin\theta_p\left(\frac{4\sin\theta_p}{2\theta_p - \sin 2\theta_p} - \frac{1}{1-\cos\theta_p}\right). \tag{30}$$

Eqs. (27) involve, for instance, the derivative of the half-angle of plate current flow $\theta_p$ with respect to the fundamental component of plate voltage, $E_p$. This derivative can readily be calculated from (2) and Fig. 4 by indicating thereon the change in the swing line implied by the increment of $E_p$. Three other derivatives of such half angles are also required and can be calculated. All four of these are summarized in (31):

$$\begin{aligned} E_p\frac{\partial\theta_p}{\partial E_p} &= \operatorname{ctn}\theta_p, & -E_c\frac{\partial\theta_p}{\partial E_c} &= \frac{\cos\theta_g}{\sin\theta_p}\,\frac{1}{1-1/\mu\rho} \\ E_p\frac{\partial\theta_g}{\partial E_p} &= \operatorname{ctn}\theta_g, & -E_c\frac{\partial\theta_g}{\partial E_c} &= \operatorname{ctn}\theta_g. \end{aligned} \tag{31}$$

The amplification factor, $\mu$, enters the above equations through the slope of the cutoff line in Fig. 4. If the tube were an ideal pentode, the cutoff line would be horizontal but displaced below the axis. Calculation shows that the resulting equations for this case derive from those given by putting $\mu = \infty$. In other words, (31) are still valid for an ideal pentode.

In the following, a further approximation, namely $\mu\rho \gg 1$, is made. This drops $\mu$ from the criteria altogether. By use of (26), (28), (29), (30), and (31), it is possible to reformulate (27) into the more compact formulas:

$$\begin{aligned} \sigma_p &= \sigma_\pi + \psi\operatorname{ctn}\theta_p, & \beta_p &= \beta_\pi + \psi\frac{\cos\theta_g}{\sin\theta_p} \\ \sigma_c &= \sigma_\gamma + \frac{1}{\theta_g}\operatorname{ctn}\theta_g, & \beta_c &= \beta_\gamma + \frac{1}{\theta_g}\operatorname{ctn}\theta_g. \end{aligned} \tag{32}$$

Then by use of relation (28), the criteria (24) can be put into the simpler form:

$$\begin{gathered} (1+\beta_c) + \frac{T_c}{T_L}(1-\delta+\delta\sigma_c-\sigma_p) > 0 \\ (1+\beta_c)(1-\delta-\sigma_p) + \sigma_c(\beta_p+\delta) > 0. \end{gathered} \tag{33}$$

Relations (32) and (33) together present the criteria derived within the approximation of (25). In this form the criteria are reasonably simple, and can be used without too much trouble.

The use of the criteria would be warranted only in case the Class C constant current design procedure were also carried out. This is not always done for small low power oscillators, since they can often be adjusted experimentally. But with oscillators of considerable power, it is often worthwhile to carry through the constant current design procedure. In this case, the calculation of the double logarithmic derivatives of the peak values of current involves no great additional labor. Once this is done, the principal raw material of formulas (32) is at hand. It is then a simple matter to introduce this into the criteria (33).

An examination of the criteria in (33) shows that the second of them does not involve the grid time constant. This second one is violated on those occasions when the oscillator envelope would be unstable, no matter what grid condenser, $C_c$, is chosen. This means that the chosen design is intrinsically unstable, but it does not preclude that, with the values of $R_0$ and $R_c$ already chosen, the oscillator might not find some other location of the swing line and there oscillate stably. If, however, the second criterion is satisfied but the first is not, then the grid time constant is involved.

Of the quantities involved in criteria (33), only $\sigma_p$ can be negative. All the others are intrinsically positive. The first of the criteria can only be violated in case the second parenthesis is negative. Since $\delta$ is always less than one, this cannot possibly happen if $\sigma_p$ is negative. A negative $\sigma_p$ is always obtained under a very light load, for in this case the swing line penetrates beyond the maximum value of plate current. However, in extreme cases, the assumption of a sinusoidal current wave shape eventually fails, and the more general criteria (24) would be required. However, the analysis indicates and experience verifies, that an unloaded oscillator does not block.

In case the loading is sufficient to make $\sigma_p$ so positive that the second parenthesis of the first criterion is negative, the criterion will be violated if the grid time constant is large enough. However, violation can always be removed by making the grid time constant smaller, i.e., by using a grid condenser that is smaller. This is the customary medicine for blocking.

To facilitate the use of the criteria, it is convenient to calculate all relevant values of the function $\psi$ of the plate half angle of flow. A rough plot is shown in Fig. 8.

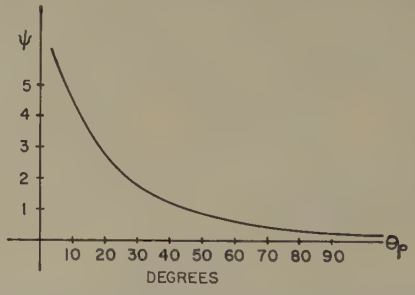

Fig. 8—Rough plot of the function $\Psi(\theta_p)$.

## Experimental Results

The criteria (33) were presented to my graduate class in "Pulsing and Synchronizing Circuits" in the fall of 1950, whence a graduate student, R. de Sobrino, undertook to verify the results experimentally.[9]

Using an Eimac 3C24 triode (at about 1,000 volts and 30 watts) de Sobrino applied the criteria in over 30

[9] R. de Sobrino y de la Sierra, "Blocking Criterion for Power Oscillators," M. E. E. Thesis, Polytechnic Institute of Brooklyn; 1951.

cases. He found the second of criteria (33) always satisfied and used the first to determine the value of grid condenser at the threshold of blocking. As long as the ratio $E_\pi/E_\gamma > 1.1$ (which is normal), he found the calculated values to lie on the conservative side of the experimentally determined values by 6 to 42 per cent. He also adjusted the oscillator for a negative value of $\sigma_p$, and verified the prediction that it would not block for any value of grid condenser.

In one illustrative case, the values

$$\begin{aligned} E_b &= 990 \text{ v}, & E_\pi &= 190 \text{ v} \\ -E_c &= 240 \text{ v}, & E_\gamma &= 128 \text{ v} \end{aligned} \tag{34}$$

were chosen as the four arbitrary parameters. These immediately yield:

$$E_p = 800 \text{ v}, \qquad E_g = 368 \text{ v}. \tag{35}$$

Reference to the Eimac constant current sheet for the 3C24 triode yielded:

$$\begin{aligned} I_\pi &= 286 \text{ ma}, & I_\gamma &= 93 \text{ ma} \\ \theta_p &= 52.8°, & \theta_g &= 49.5°. \end{aligned} \tag{36}$$

Using (26) and (3) de Sobrino found:

$$\begin{aligned} & & I_p &= 97.2 \text{ ma} \\ I_c &= 12.5 \text{ ma}, & I_g &= 25 \text{ ma} \end{aligned} \tag{37}$$

whence one calculates:

$$\begin{aligned} P_L &= 38.8\, W, & P_d &= 4.6\, W \\ R_L &= 8.24\, K, & R_c &= 19.2\, K \\ & \delta = .12. \end{aligned} \tag{38}$$

So much for the steady state design. Next, using 10 per cent voltage increments (±whichever the better choice) on the Eimac chart, de Sobrino reported:

$$\begin{aligned} \sigma_\pi &= \frac{286 - 225}{286} \cdot 10 = 2.1, & \sigma_\gamma &= \frac{93 - 50}{93} \cdot 10 = 4.6 \\ \beta_\pi &= \frac{286 - 228}{286} \cdot 10 = 2.0, & \beta_\gamma &= \frac{93 - 63}{93} \cdot 10 = 3.1. \end{aligned} \tag{39}$$

From (30) and (36) he found: $\psi = .88$.[10] Calculating the trigonometric functions and using (32) he got:

$$\begin{aligned} \sigma_p &= 2.1 + .66 = 2.8, & \sigma_c &= 4.6 + .98 = 5.6 \\ \beta_p &= 2.0 + .71 = 2.7, & \beta_c &= 3.1 + .98 = 4.1. \end{aligned} \tag{40}$$

Using this in (33):

$$\begin{gathered} (1 + 4.1) + \frac{T_c}{T_L}(.88 + .12 \cdot 5.6 - 2.8) > 0 \\ (1 + 4.1)(.88 - 2.8) + 5.6(2.7 + .12) > 0. \end{gathered} \tag{41}$$

The last of the above is satisfied, and the first yields:

$$\frac{T_c}{T_L} = \frac{R_c C_c}{2 R_L C} < \frac{5.1}{1.3} = 3.9, \tag{42}$$

which, with the values given for $R_c$ and $R_L$, gives

$$C_c < 3.4C. \tag{43}$$

Now, using the chosen value of $E_b$ and the calculated value of $R_c$ in an experimental setup, de Sobrino then adjusted $\rho$ and $R_L$ to obtain the design center values of $E_P$ and $E_g$. This put the oscillator on the design values. In the experimental setup, he increased $C_c$ from an initial small value, and found self-modulation started at

$$C_c = 4.15C.$$

The error in prediction was about 20 per cent.

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[10] The $\psi$ used in de Sobrino's thesis is different. Actually $\psi = (\sin\phi_p)\psi_{\text{sob}}$. Also some slight numerical corrections in de Sobrino's text have been made.

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# The Reduced Range in a Radar Subjected to an External Noise Generator*

UGO TIBERIO†

*Summary*—**When a radar is subjected to an external noise generator there is a reduction of range which may be calculated by an easy analytical method if some simplifying hypotheses are adopted. This paper describes such a method for two typical cases: (a) the noise generator (n.g.) is carried by the target, (b) the n.g. is in a different fixed place. The discussion is developed first in relation to a free-space condition, leading to a determination of the "reduced range index." It is then extended to a condition in which the reflection from ground must be taken into account, the ground being sea water.**

**Finally, the visibility factor in a radar influenced by an external noise generator is briefly considered.**

## INTRODUCTION

THE CALCULUS OF RADAR RANGE has been the subject of an excellent paper by Norton and Omberg[1] and of a number of other studies.[2] In these works only the noise caused by the receiver has been considered. However, in some cases there may also

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* Original manuscript received by the IRE, January 5, 1953; revised manuscript received, June 2, 1953.

† Istituto di Ellettrotecnica, della Universita di Pisa, Pisa, Italy.

[1] K. A. Norton and A. C. Omberg, "The maximum range of a radar set," PROC. I.R.E., vol. 35, p. 4; January, 1947.

[2] L. N. Ridenour, "Radar System Engineering," McGraw-Hill Book Co., New York, N. Y. See also for some old studies, U. Tiberio, "Measurement of distance by means of ultra short waves (radiotelemetry)," *Alta Frequenza*, vol. VIII, p. 305; May, 1939. U. Tiberio, "Introduzione alla radiotelemetria (radar)," Ufficio Storico Ministero Marina, Rome, Italy; 1946.

be an external noise generator, as, for instance, in some military uses, which causes additional noise in the radar receiver. The echo-noise ratio, in this case, is dependent on the relative position of the radar and the generator, so that the range is reduced correspondingly. This dependence and range reduction is discussed below[3] and some practical formulas are derived.

The discussion is divided in three parts: I. reduced range of a radar operating in a free-space condition against a standard aircraft; II. reduced range of a radar operating at low height on the sea against a ship as target; III. visibility factor. In each of the first two parts two cases are considered: *A*. the noise generator (n.g.) carried by the target itself, *B*. the n.g. in a distinct fixed place.

In accordance with Norton and Omberg,[1] the term "range index" is used to mean the distance at which a standard aircraft, i.e., one having an equivalent surface of 30 square meters, is detected with a probability of 50 per cent when only receiver-induced thermal noise is present. "Visibility factor," is defined as the ratio between echo peak power and noise average power under the said 50 per cent detection-probability condition. This factor may assume one value in reference to noise induced by the n.g. and a different value in reference to thermal noise of the receiver, since the statistical character of the two types of noise may differ.

In the discussion some simplifying assumptions are made, giving rise to errors which in the main are tolerable in all practical cases.

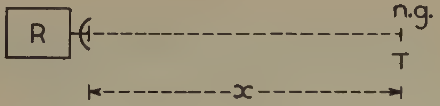

Fig. 1—Case I-A: *R*, radar; *T*, target carrying noise generator *N.G.*

## I. Reduced Range in Free Space

### *A. N.G. Carried by Target*

For this case (Fig. 1), let us consider a standard target placed on the radiation axis of the radar antenna at a distance $x$. The echo power may be expressed as

$$P_e = \frac{GP\sigma A}{(4\pi)^2x^4} = \frac{G^2\lambda^2P\sigma}{(4\pi)^3x^4} \tag{1}$$

where

$G$ = gain factor of the radar antenna,
$P$ = radar peak power,
$\sigma$ = target equivalent surface (echoing area),
$A = G(\lambda^2/4\pi)$ = equivalent surface of radar antenna.

The noise power $P_n$ in the radar receiver results from the combination of thermal and induced noises. The latter has a power

$$P_i = \frac{G'P'A}{4\pi x^2} = \frac{G'P'G\lambda^2}{(4\pi)^2x^2} \tag{2}$$

where

$P'$ = the fraction of n.g. power which lies in the radar band,
$G'$ = n.g. antenna gain in the radar direction.

When the induced and thermal noises show the same statistical character, we can simply write:

$$P_n = P_i + P_{th}$$

where $P_{th}$ indicates the thermal noise power, $P_{th} = 4FKTB$ ($F$ = receiver noise factor, $T$ = absolute temperature, $K$ = Bolzmann's constant, $B$ = receiver bandwidth).

When the statistical characters, instead, are different, we must write:

$$P_n = kP_i + P_{th}, \tag{3}$$

in which:

$$k = \frac{V}{V'}, \tag{4}$$

with the ratio between the visibility factors as related to induced and thermal powers:

$$V' = \frac{P_{ei}}{P_i}, \qquad V = \frac{P_{ei}}{P_{th}}, \tag{4a}$$

where $P_{ei}$ is the echo power which gives the said 50 per cent detection-probability condition, in the presence of $P_i$ or $P_{th}$ noise power.

The echo-noise ratio $\gamma_x$, therefore, should be written

$$\gamma_x = \frac{P_e}{kP_i + P_{th}} = \frac{G^2\lambda^2P\sigma}{4\pi x^2[kG'P'G\lambda^2 + (4\pi)^2x^2P_{th}]}. \tag{5}$$

If we let $\gamma_x = V$, and $\sigma = \sigma_1$ = the equivalent surface of a standard target, and solve with respect to $x$, we then have the "reduced range index" $X_n$, i.e., the range below which the echo-noise ratio is greater than the visibility factor.

In many practical circumstances, the term $P_{th}$ may be neglected in comparison to that containing $P'$.

In that case we have:[4]

$$X_n = \left(\frac{GP\sigma_1}{4\pi kVG'P'}\right)^{1/2}. \tag{6}$$

This formula may be written in a convenient form by putting it in terms of the range index $X$, which can be deduced from (1) by assuming $P_e = VP_{th}$, $\sigma = \sigma_1$, and solving with respect to $x$:

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[3] A preliminary discussion of this matter has been published in U. Tiberio: "Echo and noise in a radar subjected to active jamming," *Alta Frequenza*, vol. XXI, p. 137–151; 1952.

[4] When the term $P_{th}$ cannot be neglected, we should write, instead of (6):

$$X_n = \left\{\frac{G\lambda}{4\pi}\left[\left(\frac{kG'P'\lambda}{2(4\pi)^2P_{th}}\right)^2 + \frac{P\sigma}{4\pi VP_{th}}\right]^{1/2} - \frac{KG'P'G\lambda^2}{2(4\pi)^3P_{th}}\right\}^{1/2}, \tag{6c}$$

which is derived in straightforward manner.

It should be noted that the value of $\gamma_x$ in (5) becomes the same as $V$ in those cases when $P_{th}$ may be neglected and it is assumed that $\sigma = \sigma_1$. This is in accordance with the assumptions made.

$$X = (G\lambda)^{1/2}\left(\frac{P\sigma_1}{(4\pi)^3 V P_{th}}\right)^{1/4}. \qquad (7)$$

So (6) becomes:

$$X_n = \frac{4\pi}{\lambda}\left(\frac{P_{th}}{kGG'P'}\right)^{1/2} X^2. \qquad (6a)$$

As an example, consider a case in which $X=100$ km, $\lambda=10$ cm, $k=0.5$, $G=4(10)^2$, $G'=10$, $P'=5W$, $P_{th}=5(10)^{-13}W$. Draw $X_n=8.8$ km. This is the range at which the echo of a medium aircraft carrying the n.g. may be seen with a probability of 50 per cent, so that at smaller ranges the echo can be clearly observed, while at greater ranges the echo image becomes practically submerged by noise. In that case we may read only direction, which is indicated by the noise trace.

When there is a target having an equivalent surface $\sigma$, then we must multiply $X_n$ by a factor $\sqrt{\sigma/\sigma_1}$; so that a ship having $\sigma=3{,}000$ square meters may be seen at a range 88 km (taking no account of ground reflections).

Often the radar operator may evaluate the noise voltage $v_i$ which is induced at some moment, together with the approximate range $d$ at which the target is placed at that moment. The product $G'P'$ in that case can be calculated from (2) by putting $x=d$:

$$G'P' = \frac{(4\pi)^2 d^2}{G\lambda^2}\cdot\frac{v_i'^2}{R} \qquad (8)$$

where $R$ is the resistance on which $v_i'$ is acting, so that $P_i'=v_i'^2/R=$ value that the noise power $P$ assumes at distance $d$. Knowing that $P_{th}=v_{th}^2/R$, we have from (6a):

$$X_n = \frac{v_{th}}{v_i'd}\,\frac{X^2}{k^{1/2}}, \qquad (6b)$$

which is a form suitable for some applications. As an example, take a case where $v_i'/v_{th}=10$, $d=60$ km, $k=0.5$, $X=100$ km; then we have: $X_n=23.6$ km.

When the radar and n.g. antennas are not mutually pointed, the factors $G$ and $G'$ should be accordingly modified.

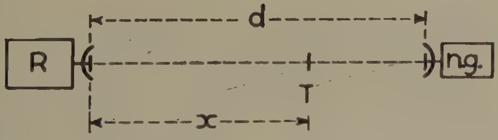

Fig. 2—Case I-B: N.G. in a fixed place on the radiation axis on which target also lies.

### B. N.G. in a Distinct Fixed Place

In this case (Fig. 2, above), the induced noise power is calculated by the expression:

$$P_i' = \frac{G'P'G\lambda^2}{(4\pi d)^2}, \qquad (9)$$

where $d$ is the distance between the radar and the n.g. The n.g. is pointed towards the radar and placed on its radiation axis; the target also lies on this axis. Echo-noise ratio therefore is written:

$$\gamma_x = \frac{P_e}{kP_i' + P_{th}} = \frac{(G\lambda d)^2 P\sigma}{4\pi x^4[(4\pi d)^2 P_{th} + kG'P'G\lambda^2]}. \qquad (10)$$

Now letting $\gamma_x=V$, $\sigma=\sigma_1$, and neglecting $P_{th}$, then we have the reduced range index:[5]

$$X_n = d^{1/2}\left(\frac{GP\sigma_1}{4\pi G'P'kV}\right)^{1/4}. \qquad (11)$$

Taking (7) into account, this formula can be written:[6]

$$X_n = \left(\frac{4\pi d}{\lambda}\right)^{1/2}\left(\frac{P_{th}}{kGG'P'}\right)^{1/4} X. \qquad (11a)$$

When the radar operator can evaluate the induced noise voltage $v_i$, it is convenient, remembering (8), to write (11) in the form:

$$X_n = \left(\frac{v_{th}}{v_i'}\right)^{1/2}\frac{X}{k^{1/4}}. \qquad (11b)$$

When the radar and n.g. antennas are not mutually pointed, the factors $G$ and $G'$ should accordingly be modified.

## II. RADAR OPERATING AT LOW HEIGHT ON SEA AGAINST A SHIP

### A. N.G. Carried by Target

The study of this case presents some difficulties if we try to develop a group of general, exact formulas. To avoid these difficulties, we will divide the general case into four typical sub-cases, which have been indicated in Fig. 3, on the following page, and adopt some acceptable approximations. We shall indicate with $X_n'$ the "naval" target, as related to a ship having an echoing area.

1. The first sub-case [Fig. 3(a)] is characterized by the fact that sea surface may be considered a plane because of the small ranges to be considered; furthermore, $\lambda/h$ ratio has a small value. We suppose that n.g. has a lobe-compensated antenna, so that noise radiation is uniformly distributed in the vertical plane. Under this assumption we can write

$$P_i = \frac{2G'P'A}{4\pi x^2} \qquad (12)$$

where $A$ indicates the equivalent area of radar antenna, and the factor 2 in the numerator takes into account a perfect reflection from the sea surface. The expression of echo power is

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[5] When the term $P_{th}$ cannot be neglected, we must write:

$$X_n = (G\lambda d)^{1/2}\left\{\frac{P\sigma_i}{4\pi V[(4\pi d^2 P_{th} + kG'P'G\lambda^2]}\right\}^{1/4}. \qquad (11c)$$

[6] If we settle a value for $X_n/X$ ratio, then solve (11a) with respect to $d$, we derive the "action radius" of n.g.: that is, the range under which the reduction range ratio is inferior to a determined value.

$$P_e = \frac{4GP\sigma A}{(4\pi)^2 x^4}, \tag{13}$$

which is unlike (1) by the factor 4 in the numerator, taking into account a perfect reflection from sea water.

The echo-noise ratio, when $P_{th}$ is neglected, must be written:[7]

$$\gamma_x = \frac{GP\sigma}{2\pi kG'P'x^2}. \tag{14}$$

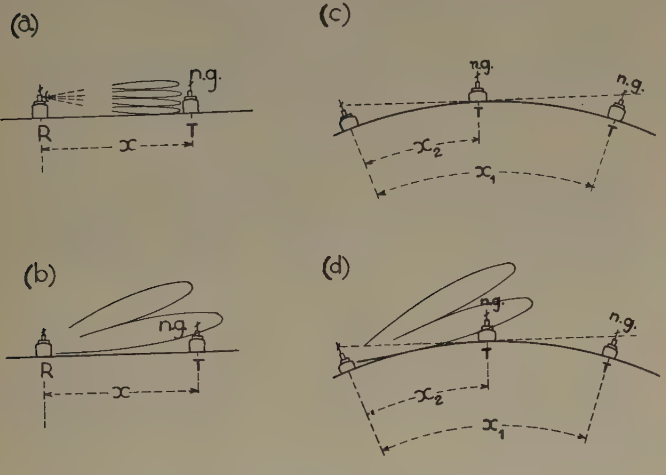

Fig. 3—The four sub-cases into which case II-A has been divided.

The reduced naval range then becomes:

$$X_n' = \left(\frac{GP\sigma}{2\pi kVG'P'}\right)^{1/2}, \tag{15}$$

which can also be expressed by the free-space standard range index $X$:

$$X_n' = \frac{4\pi}{\lambda}\left(\frac{2P_{th}\sigma}{kGG'P'\sigma_1}\right)^{1/2} X^2. \tag{15a}$$

When the radar operator can determine the induced noise voltage $v_i'$, which takes place corresponding to a distance $d$ that he can closely estimate at some time, it is convenient to replace $G'P'$ by an expression which is deduced from (12), letting $X=d$ and substituting $v_i'^2/R$ for $P_i$:

$$G'P' = \frac{2\pi d^2}{A}\,\frac{v_i'^2}{R}.$$

Remembering that $A = G(\lambda^2/4\pi)$, $P_{th} = v_{th}^2/R$, then:

$$X_n' = \frac{2v_{th}}{v_i'd}\left(\frac{\sigma}{k\sigma_1}\right)^{1/2} X^2. \tag{15b}$$

2. In the second sub-case [Fig. 3(b)], we suppose that the sea has a plane surface, but $\lambda/h$ ratio is not small. Therefore "low-coverage" short-range formulas must be used for field strength calculations. This "low-coverage" condition is characterized by the fact that the phase difference between direct and reflected rays is nearly $\pi$, with a difference $\leq \frac{1}{2}$ radian. Since this difference is nearly $4\pi h'y/\lambda x$, where $h'$ denotes n.g. height and $y$ the height of the point in which the field is considered, this condition may be written:

$$\frac{2\pi h'y}{\lambda x} \leq 1. \tag{16}$$

The noise power, which is adsorbed by radar antenna placed at height $h$, may be calculated by the known expression[8]

$$P_i = 4\pi G'P'\left(\frac{hh'}{\lambda x^2}\right)^2 A. \tag{17}$$

An approximate calculation of the echo power may be made by assuming a rectangular shape, so that the surface of one of its elementary horizontal strips is then

$$d\sigma = \frac{\sigma}{H}\,dy \tag{18}$$

where $H$ is the rarget's height. The radar-ray power impinging on this strip is then

$$P_{xy}d\sigma = \frac{\sigma}{H}\,p_{xy}dy, \tag{19}$$

where $p_{xy}$ denotes the radar-ray-power density at height $y$ and distance $x$. The expression of $p_{xy}$ can be written, by analogy to (17), as

$$p_{xy} = 4\pi GP\left(\frac{hy}{\lambda x^2}\right)^2. \tag{20}$$

The elementary contribution to echo power by the strip may be written by applying further the above analogy:

$$dP_e = 4\pi p_{xy}\left(\frac{yh}{\lambda x^2}\right)^2 A\,d\sigma = (4\pi)^2 GP\left(\frac{hy}{\lambda x^2}\right)^4 A\,d\sigma. \tag{21}$$

The whole echo-power is easily obtained by an integration, which is given in Appendix I. Then the naval reduced range is given by:

$$X_n' = \frac{4\pi H}{\lambda}\left(\frac{h}{h'}\right)^{1/2}\left(\frac{\sigma P_{th}}{5kG'P'\sigma_1}\right)^{1/4} X, \tag{22}$$

which is characterized by the fact that the reduced range is proportional to $X$ instead of $X^2$. There is then a minor advantage in increasing $X$ to overcome noise.

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[7] When $P_{th}$ cannot be neglected, we have an expression analogous to (5) which is different from this only by a factor 2.

[8] The field resulting from the combination of direct and reflected rays has the approximate value

$$E_i = \frac{4\pi h'h}{\lambda x}\,E_{0i},$$

where $E_{0i}$ denotes the intensity of each of these rays. On the other hand:

$$E_{0i} = \left(120\pi\,\frac{G'P'}{4\pi x^2}\right)^{1/2}.$$

If these formulas are combined, and $P_i = E_i^2/120\pi$ is derived, then (17) is obtained.

Eq. (22) can also be written:

$$X_n' = \frac{4\pi H h}{\lambda d}\left(\frac{\sigma G}{5k\sigma_1}\right)^{1/4}\left(\frac{v_{th}}{v_i'}\right)^{1/2} X, \tag{22a}$$

which may be employed by a radar operator if he can evaluate the ratio between induced noise voltage $v_i'$ and thermal noise voltage $v_{th}$ which takes place at some time corresponding to a distance $d$ roughly known.

3. In the third sub-case [Fig. 3(c)], $\lambda/h$ has a small value as in the first but the range is large, so that the curving of the earth must be taken into account.

For the $x_2$ interval, indeed, we may, with sufficient accuracy, use the formulas already derived for the first sub-case. Between ranges $x_2$ and $x_1$, however, the partial illumination of the target must be considered. By assuming here also a rectangular shape for the target, we can write:

$$\sigma_x = \frac{H - \eta}{H}\sigma \tag{23}$$

where $H$ indicates the height of target, $\eta$ the depression below radar horizon at range $x$, and $\sigma_x$ the fraction of $\sigma$ which is illuminated. The depression $\eta$ has the well-known value:

$$\eta = \frac{(x - x_2)^2}{2\rho} \tag{24}$$

in which $\rho$ is the radar radius of the earth ($\frac{4}{3}$ geographical radius); therefore:

$$\sigma_x = \frac{\sigma}{H}\left[H - \frac{(x - x_2)^2}{2\rho}\right]. \tag{25}$$

The expressions of $P_e$ and $P_i$ may now be written by analogy to (12) and (13), taking into account the fact that the reflection coefficient is zero for a ray tangent to sea surface, so that we have no reinforcement by effect of the sea; the divergence factor, however, is zero in this case. In Appendix II the expression of $\gamma_x$ is derived, and consequently formulas suitable for the approximate calculation of $X_n'$ in $x_1 - x_2$ interval are obtained.

4. The study of the fourth sub-case [Fig. 3 (*d*)] at present is a matter of lesser interest, since long waves are today almost never used in applications of this kind. However, since there are some cases in which $\lambda/h$ is not small and the curvature of the earth must be taken into account, the criterions which may be applicable will be discussed briefly. Since the analytical expression of the field has a complicated form in this case, it is convenient to use a graphical procedure, as follows:

a) draw the curve in which the noise induced power $P_i$ is related to distance $x$;
b) draw the curve in which the echo power $P_e$ is related to $x$;
c) then determine the value of $x$ for which the ratio between the two powers equals the visibility factor.

To derive the $P_i$ curve, it is suitable to use graphs which give the field at short distances and can be traced by known methods.[9] Fig. 4(a) shows the behavior of a typical family of curves, which gives the field $E_n$ of the noise generator in relation to the distance and to the height from ground. A dot-dash curve is shown, having a constant ordinate equal to radar height. We must read the values $E_{nx}'$ of $E_n$ which fall on this curve, and then calculate corresponding induced noise powers:

$$P_{nx}' = \frac{E_{nx}'^2 A}{120\pi}. \tag{26}$$

Fig. 4(b) shows the behavior of the analogous family of curves, which give the contribution $E_e$ to the echo-field when a one square meter obstacle is placed at various heights and distances. For every target distance, the resulting echo field may be calculated:

$$E_{ex} = \int_\sigma E_e d\sigma, \tag{27}$$

from which resulting echo power is derived, as follows:

$$P_{ex} = \frac{E_{ex}^2 A}{120\pi}. \tag{28}$$

Fig. 4(c) shows behavior of $P_{ex} = f(x)$ and $P_{nx} = f(x)$, which makes it possible to obtain range $X_n$, below which echo-noise ratio overcomes visibility factor.

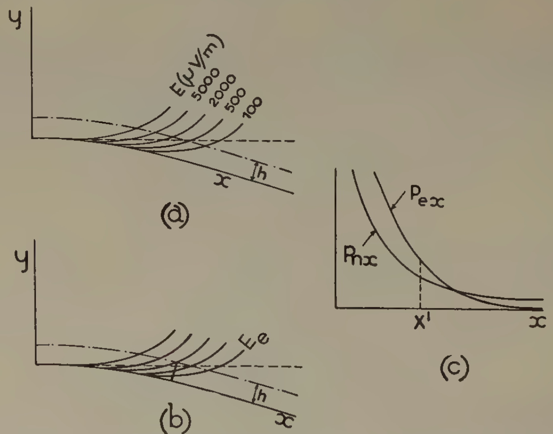

Fig. 4—Graphical procedure for finding $X_n'$, in a case where $\lambda/h$ is not small, and curving of the earth must be taken into account (the fourth sub-case of II-B).

## B. N.G. in a Distinct Fixed Place

Fig. 5, on the following page, shows the four main sub-cases analogous to those which have already been discussed. We may therefore readily write the corresponding formulas.

1. In the first sub-case of II-B, (12) becomes:

$$P_i' = \frac{2G'P'A}{4\pi d^2} \tag{29}$$

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[9] C. R. Burrows and S. S. Atwood, "Radio Wave Propagation," Academic Press, New York, N. Y.; 1949.

since here the n.g. distance remains equal to a fixed value $d$, while (13) remains unchanged, so that (14) should be written:

$$\gamma_x = \frac{P_e}{KP_i'} = \frac{GP\sigma d^2}{2\pi kG'P'x^4}. \qquad (30)$$

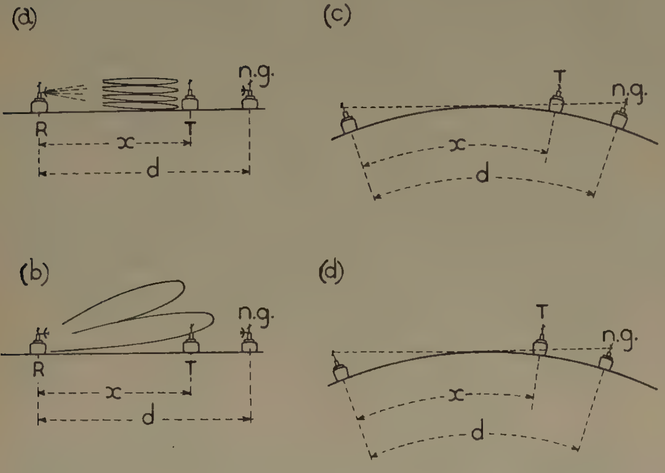

Fig. 5—The four main sub-cases which may be encountered in case II-B.

The reduced range, as a function of the free-space range index, is then:

$$X_n' = \left(\frac{\pi d}{\lambda}\right)^{1/2}\left(\frac{32\sigma P_{th}}{kGG'P'\sigma_1}\right)^{1/4} X. \qquad (31)$$

When the radar operator is able to evaluate the ratio between the induced noise voltage $v_i'$ and the thermal noise voltage $v_{th}$, it is convenient to write (2) in the form:

$$X_n' = \left(\frac{4\pi\sigma}{k\sigma_1}\right)^{1/4}\left(\frac{v_{th}}{v_i'}\right)^{1/2} X. \qquad (31a)$$

2. In the second sub-case, from (17), letting $x=d$, we obtain the constant induced noise $P_i'$:

$$P_i' = 4\pi G'P'\left(\frac{hh'}{\lambda d^2}\right)^2 A \qquad (32)$$

while (21) remains unchanged. Thus it is easy to calculate $\gamma_x$, and then (see Appendix I) derive the reduced range:

$$X_n' = (4\pi Hd)^{1/2}\left(\frac{h}{h'}\right)^{1/4}\left(\frac{\sigma P_{th}}{5kGG'P'\sigma_1}\right)^{1/8} X^{1/2}. \qquad (33)$$

When the ratio between the induced and thermal noise voltages has been evaluated, (33) may be written in the form:

$$X_n' = (4\pi Hh)^{1/2}\left(\frac{\sigma}{5k\sigma_1}\right)^{1/8}\left(\frac{v_{th}}{v_i'}\right)^{1/4} X^{1/2}. \qquad (33a)$$

3. In the third sub-case, the expression of echo power remains equal to that considered in the third (c) sub-case of II-A, but the induced noise power assumes a constant value $P_i'$:

$$P_i' = \frac{G'P'A}{4\pi d^2}. \qquad (34)$$

$\gamma_x$ is derived in Appendix II. A graphical solution is advised to determine the reduced range $X_n'$. The analytical calculation of this parameter offers some difficulties.

4. The graphical solution, which has already been described in reference to the fourth (d) sub-case of II-A, may also be used here. The only change is in the fact that $P_{nx}'$ has a constant value. The $P_{ex}$ curve should be drawn as in the preceding paragraph.

## III. The Visibility Factor

Information theory gives a general method for evaluating the amount of information contained in a signal in the presence of noise. Therefore, we can express the visibility of an echo as a function of the parameters by which echo and noise are characterized.

According to this theory, the "visibility" has a statistical characteristic, and should be studied by means of the criterions of classical (Boltzmann) statistics. "Visibility factor," as defined in the Introduction, involves a condition in which there is a 50 per cent probability that the right echo image will be selected from a false indication caused by sporadic fluctuating pulse indications due to noise. There is an obvious correspondence between this definition and that of "bit," which is assumed as unity in information theory.

A previous study[10,11] of how to calculate visibility factor on a statistical basis gives the following formula:

$$v_e = E_n B^{1/2} \frac{\alpha}{f_r^{1/4}}, \qquad (35)$$

where $v_e$ = rms maximum echo-voltage, $E_n$ = rms noise voltage for cycle, $B$ = bandwidth, $f_r$ = frequency of pulse repetition, $\alpha$ = coefficient.

In the derivation of (35) a factor $1/(BT_i)^{1/4}$, where $T_i$ is the pulse duration, was conglobated in coefficient $\alpha$, since $BT_i$ in the common radar has a constant value $=2$. For this discussion, we should take this factor into account and rewrite:

$$v_e = E_n \frac{\alpha}{2}\left(\frac{B}{f_rT_i}\right)^{1/4}. \qquad (35a)$$

Taking the square of this expression, dividing by $R$ = equivalent resistance of first receiver circuit, we have:

$$P_{ei} = P_n \frac{\alpha^2}{4}\left(\frac{B}{f_rT_i}\right)^{1/2}, \qquad (36)$$

where $P_{ei}$ is the echo power at which the probability of selecting the right echo is 50 per cent, and $P_n$ = noise power. According to the definition of visibility factor $V$, we have:

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[10] U. Tiberio, "Signal-noise ratio in receivers having an oscillographic indicator," *Alta Frequenza*, vol. 7, p. 316; 1943.

[11] U. Tiberio, "Minimum detectable radar signal," Proc. I.R.E., vol. 36, p. 1261; October, 1947.

$$V = \frac{P_{ei}}{P_n} = \frac{\alpha^2}{4}\left(\frac{B}{f_r T_i}\right)^{1/2}, \qquad (37)$$

which is valid for the conditions under which (35) was derived namely: (a) the radar has a fixed orientation and is pointed on target so that $f_r$ pulses per second are impinging on that target and gives the possibility of detection; (b) the thermal noise is acting alone ($P_n = P_{th}$), so that the statistical character of received noise is determined by the receiver bandwidth $B$.

In order for (37) to apply to the case under examination here, we should use the number of pulses which actually impinge on the target in each second, $f_i$ instead of $f_r$. Furthermore $B$ should be replaced by the resultant bandwidth $B'$ which actually determines the statistical character of received noise:

$$V = \frac{\alpha^2}{4}\left(\frac{B'}{f_i T_i}\right)^{1/2}. \qquad (38)$$

When radar as a $B$-scan indicator, having a searching angle $\beta$ and a coverage angle $\delta$, the value of $f'$, the so-called "insistence frequency," results in:

$$f_i = \frac{\delta}{\beta} f_r. \qquad (39)$$

The resultant bandwidth $B'$ equals $B$ when, as is frequently the case today, particularly in doppler cw systems, n.g. has a much larger bandwidth $B_n$ in which the radar bandwidth is contained. When, on the contrary, $B_n$ is much smaller than $B$ and furthermore is contained in that of radar, we must take into account $B_n$ instead of $B$. In intermediate cases a more accurate study of the statistical character of the resultant noise, as filtered in the receiving amplifier, must be made.

## APPENDIX I

## DERIVATION OF REDUCED RANGE FORMULAS IN THE CASE OF LOW HEIGHT ON PLANE SEA SURFACE, $\lambda/h$ BEING SMALL

### *A. N.G. Carried by Target (Second Sub-Case of II-A)*

Eq. (21), replacing $d\sigma$ by its expression, becomes:

$$dP_e = \frac{(4\pi)^2 GP\sigma A}{H}\left(\frac{h}{\lambda x^2}\right)^4 y^4 dy \qquad (21a)$$

which, by integration, gives

$$P_e = \frac{(4\pi)^2 GP\sigma A}{H}\left(\frac{h}{\lambda x^2}\right)^4 \int_0^H y^4 dy$$

$$= \frac{(4\pi)^2 GP\sigma A}{5}\left(\frac{Hh}{\lambda x^2}\right). \qquad (21b)$$

$\gamma_x$ then results, by neglecting $P_{th}$ and remembering (17)

$$\gamma_x = \frac{P_e}{kP_i} = \frac{4\pi GP\sigma}{5kG'P'}\left(\frac{h}{h'}\right)^2\left(\frac{H}{x}\right)^4. \qquad (21c)$$

Putting $\gamma_x = V$, and solving with respect to $x$, gives the reduced range $X_n'$

$$X_n' = H\left(\frac{h}{\lambda h'}\right)^{1/2}\left(\frac{4\pi\sigma GP}{5kG'P'V}\right)^{1/4}. \qquad (21d)$$

Combining with (7) gives us (22)

$$X_n' = \frac{4\pi H}{\lambda}\left(\frac{h}{h'}\right)^{1/2}\left(\frac{\sigma P_{th}}{5kG'P'\sigma_1}\right)^{1/4} X. \qquad (22)$$

When the radar operator can evaluate the induced noise voltage $v_i'$, at a time when he knows approximately the distance $d$, it is possible to calculate the product $G'P'$ by means of (32), which may be rewritten:

$$G'P' = \left(\frac{\lambda d^2}{hh'}\right)^2 \frac{v_i'^2}{4\pi AR}, \qquad (32a)$$

taking into consideration that $P_i' = v_i'^2/R$.

Substitution in (22) gives us (22a):

$$X_n' = \frac{4\pi Hh}{\lambda d}\left(\frac{\sigma G}{5k\sigma_1}\right)^{1/4}\left(\frac{v_{th}}{v_i'}\right)^{1/2} X. \qquad (22a)$$

### *B. N.G. in a Distinct Fixed Place (Second Sub-Case of II-B)*

The ratio between (21b) and (32) is:

$$\gamma_x = \frac{P_e}{kP_i'} = \frac{4\pi GP\sigma}{5kG'P'}\left(\frac{h}{\lambda h'}\right)^2 \frac{(Hd)^4}{x^8}.$$

Putting $\gamma_x = V$ and solving with respect to $x$ gives us $X_n'$:

$$X_n' = (4\pi Hd)^{1/2}\left(\frac{h}{h'}\right)^{1/4}\left(\frac{\sigma P_{th}}{5kGG'P'\sigma_1}\right)^{1/8} X^{1/2}. \qquad (33)$$

Combining this expression with (32) gives us (32a):

$$X_n' = (4\pi Hh)^{1/2}\left(\frac{\sigma}{5k\sigma_1}\right)^{1/8}\left(\frac{v_{th}}{v_i'}\right)^{1/4} X^{1/2}. \qquad (33a)$$

## APPENDIX II

## DERIVATION OF REDUCED RANGE FORMULAS IN THE CASE OF LOW HEIGHT ON CURVED SEA SURFACE, $\lambda/h$ HAVING A SMALL VALUE

### *A. N.G. Carried by Target (Third Sub-Case of II-A)*

The expression of $P_e$ may be written by inserting $\sigma_x$ in place of $\sigma$ in (13):

$$P_e = \frac{GP\sigma A}{(4\pi)^2 x^4 H}\left[H - \frac{(x - \sqrt{2\sigma h})^2}{2\rho}\right] \qquad (40)$$

where $x_2$ is substituted by its expression: $x_2 = \sqrt{2\rho h}$, and where $h$ = radar height. The factor 4 is omitted since the reflection coefficient of a tangent ray is zero, so that there is no reinforcement from the sea surface; the divergence factor, however, is zero in that case.

The induced noise may be calculated by an expression analogous to (12):

$$P_i = \frac{G'P'A}{4\pi x^2} \qquad (41)$$

where factor 2 in the numerator has been omitted since here, too, the reflection coefficient is zero.

From (40) and (41) we now have the expression of echo-noise ratio which must be used between $x_2$ and $x_1$:

$$\gamma_x = \frac{GP\sigma}{4\pi kG'P'Hx^2}\left[H - \frac{(x-\sqrt{2\rho h})^2}{2\rho}\right]. \qquad (42)$$

If we put: $\gamma_x = V$, $X_n'$ can be derived by solving a second-degree equation in $x$:

$$X_n' = \frac{(2\rho h)^{1/2} + \left[2\rho h + 2\rho(H-h)\left(1 + \frac{8\pi k\rho G'P'HV}{GP\sigma}\right)\right]^{1/2}}{1 + \frac{8\pi k\rho G'P'HV}{GP\sigma}}. \qquad (43)$$

The radar operator may evaluate the product $G'P'$ by means of (9), which can be written:

$$G'P' = \frac{P_i'}{G}\left(\frac{4\pi d}{\lambda}\right)^2, \qquad (44)$$

when he can determine at some time the induced noise voltage and the corresponding distance $d$. Also, the factor $GP/V$ can be deduced from (7):

$$\frac{GP}{V} = \frac{(4\pi)^3 P_{th} X^4}{G\lambda^2\sigma_1} \qquad (45)$$

so that:

$$\frac{G'P'V}{GP} = \frac{\sigma_1 P_i' d^2}{4\pi P_{th} X^4} = \frac{\sigma_1}{4\pi}\left(\frac{v_i' d}{v_{th} X^2}\right)^2,$$

and consequently (43) can be written:

$$X_n' = \frac{(2\rho h)^{1/2} + \left\{2\rho h + 2\rho(H-h)\left[1 + \frac{2k\rho\sigma_1 H}{\sigma}\left(\frac{v_i'^2 d}{v_{th} X^2}\right)^2\right]\right\}^{1/2}}{1 + \frac{2k\rho\sigma_1 H}{\sigma}\left(\frac{v_i' d}{v_{th} X^2}\right)^2}. \qquad (43a)$$

This can be utilized if the value $v_i'/v_{th}$ has been determined for some known distance $d$.

### *B. N.G. in a Distinct Fixed Place (Third Sub-Case of II-B)*

The expression of echo-power remains equal to that considered in the third sub-case of II-A, namely (40), while the constant induced noise power becomes

$$P_i' = \frac{G'P'A}{4\pi d^2}$$

so that $\gamma_x$ becomes:

$$\gamma_x = \frac{GP\sigma d^2}{4\pi kG'P'Hx^4}\left[H - \frac{(x-\sqrt{2\rho h})^2}{2\rho}\right], \qquad (46)$$

which is valid when target and n.g. are placed in the $x_2 - x_1$ interval as indicated in Fig. 3. Eq. (46) may also be written:

$$\gamma_x = \frac{\sigma V X^4 v_{th}^2}{\sigma_1 kHv_1' x^4}\left[H - \frac{(x-\sqrt{2\rho h})^2}{2\rho}\right]. \qquad (46a)$$

This is preferable to use when $v_i'/v_{th}$ ratio has been measured. Since there are difficulties in the analytical solution of $X_n'$, it is advisable to resort to a graphical solution by drawing the curve $\gamma_x = f(x)$, and then determining the value of $x$ which corresponds to the crossing of this curve and $\gamma_x = V$.

* * *

# Miniature Lacquer Film Capacitors*

D. A. McLEAN† AND H. G. WEHE†

*Summary*—**Miniaturization of capacitors for low voltage applications has been restricted by lack of availability of thin dielectric films which can be handled mechanically. This restriction is not relieved by ceramics with dielectric constants of one or two thousand, because of the relatively thick films which must be used, because of the poor performance of such ceramics at elevated temperature, and because ceramics do not lend themselves to construction of wound capacitors to provide high capacitance values.**

**Lacquer film capacitors represent an attempt to overcome the restriction on dielectric thickness. Although these capacitors are still in the development stage they show considerable promise for use in transistor circuits. One type of lacquer film capacitor is made by casting a thin dielectric film on a supporting base and carrying it through the process of metallizing and slitting while supported. After stripping the film, the only mechanical process which it has to endure as a self-supporting sheet is that of being wound into capacitor units. Metallized films 0.1 mil thick have been made in appreciable quantity, and resulting capacitors are about one-seventh the size of the smallest metallized paper capacitors.**

**For fragile dielectrics, the supporting film may be wound into the capacitor unit. This type suffers in compactness when compared with the stripped lacquer film type, but its use may be justified when it is desired to use fragile dielectrics of exceptional electrical properties. It may also prove advantageous to leave the support in when building capacitors for operation at very low voltages, below about 15 volts.**

**In the Appendix to this paper, a derivation is given for the effective series-resistance of a metallized capacitor in terms of the thickness, width, and dielectric constant of the films, and the conductivity of the metallic coating.**

## INTRODUCTION

MINIATURIZATION of electronic equipment has gained increasing importance in recent years. Impetus to this trend has been contributed by several factors; the increasing complexity of electronic equipment, making it undesirably bulky when conventional components and structural methods are used; the desire for small size and weight in airborne equipment and guided missiles; and the advent of transistors, extremely small elements performing many of the functions of vacuum tubes. While each of these factors provides ample justification for effort aimed at miniaturization, the greatest stimulus comes from the transistor, whose small size challenges the designer of associated equipment, and whose small power dissipation and low operating voltages open up new possibilities for miniaturization.

With respect to capacitors, it appears that the bulk of usage in transistor circuits will allow drastically reduced working voltages as contrasted with the requirements of vacuum tube circuits. It appears, for example, that many applications will be satisfied with capacitors having ratings of 5–10 volts, and that the majority of circuit applications will be served adequately by capacitors with ratings of 50 volts or less.

In the design of low voltage capacitors, one is faced with the fact that all available insulating films are thicker than required to withstand the voltages of most transistor circuits. Furthermore, films of known materials of requisite thickness, were they available, are fragile in self-supporting form and difficult to slit and to metallize. Metallizing is necessary at present, since it constitutes the only method developed to date for making efficient use of the dielectric in low voltage capacitors. This paper describes an attempt to overcome these obstacles. The methods described are all still being perfected in the laboratory; on the other hand, some hundreds of capacitors of the types described have been constructed and tested.

To understand the importance of obtaining thin dielectric films, the role of dielectric thickness in relation to capacitor size must be fully understood.

For a metallized capacitor,[1]

$$\frac{V}{C} = 72.9 \frac{d^2}{e} \tag{1}$$

where $V$ is the volume of the capacitor in cc, $C$ the capacitance in microfarads, $d$ the dielectric thickness in mils, and $e$ the dielectric constant.

If, for example, one is forced by considerations of availability to use a dielectric five times as thick as required by the working voltage, the capacitor will be 25 times as large as necessary. The above equation takes no account of insulating margins, outer wrapping of the unit, or housing, but these will be roughly proportional to the volume of the effective part of the unit.

The importance of dielectric thickness in capacitor miniaturization is further emphasized by comparing two possible approaches to the problem of miniaturization: (1) development of methods of making metallized film capacitors using available organic materials;[1–4] and (2) use of available high dielectric constant ceramic materials.[5] Let us first consider the position of these two approaches in the current commercial picture.

Metallized paper capacitors using 0.25 mil paper to which is added about 0.03 mil of lacquer have been made successfully. The effective dielectric constant,

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* Original manuscript received by the IRE, May 25, 1954; revised manuscript received June 29, 1954.

† Bell Telephone Labs., Inc., Murray Hill, N. J.

[1] D. A. McLean, "Metallized paper for capacitors," PROC. I.R.E., vol. 38, pp. 1010–1014; September, 1950.

[2] H. G. Wehe, "Metallizing paper for capacitors," *Bell Labs. Record*, vol. 27, p. 317; September, 1949.

[3] J. R. Weeks, "Metallized paper capacitors," PROC. I.R.E., vol. 38, pp. 1015–1018; September, 1950.

[4] M. C. Wooley, et al., "Polyethylene terephthalate—its use as a capacitor dielectric," *Elec. Eng.*, vol. 71, pp. 715–717; August, 1952.

[5] G. R. Shelton and S. Marzullo, "Dielectrics for Ceramic Components," NBS Rep. No. 3294, File No. 9.1/1099, Project 0901-20-4404; May 1, 1954.

when a hydrocarbon wax is used as the impregnant, is about 4.0. In ceramics, on the other hand, film thicknesses of not less than about 5 mils are considered practical at present where any appreciable area is needed, and the highest dielectric constant in a material having suitable temperature coefficient and other properties for general use is about 1,400.

The space factor $V/C$ from (1) is therefore,

for metallized paper 1.42 cc/mf,
for ceramics 1.30 cc/mf.

It may be a surprise to many that these theoretical space factors of the two types are almost identical. When one considers the mechanical and space-saving advantages of a wound unit, especially for the higher capacitance values, better electrical properties, and mechanical ruggedness, the metallized paper capacitor obviously offers substantial advantages.

Because of simplicity of construction of capacitors built from one or two sheets of ceramic or from a single tube, high dielectric constant ceramics undoubtedly have established a place for themselves in the capacitor industry. But where capacitances above about 0.01 mf are required, the organic dielectric films appear to offer important advantages. This paper describes a type of capacitor made with organic film having a thickness of 0.1 mil and a dielectric constant of 3.8. To match this from the standpoint of miniaturization, a ceramic of $e=1,400$ would have to be reduced in thickness to 1.9 mils and would possess to an extreme degree the mechanical limitations mentioned above.

With the advent of Mylar, a synthetic polyester film, metallized Mylar has entered the miniaturization picture.[4] In many applications, metallized Mylar will result in smaller capacitors than have heretofore been available. For very low voltage capacitors, on the other hand, metallized 0.1 mil lacquer film capacitor units are 30 times smaller in volume than 0.5 mil metallized Mylar and 8 times smaller than 0.25 mil metallized Mylar. If one assumes the same potential gradient in both films, then a 5:1 and 2.5:1 voltage rating can be traded for a size reduction of 30:1 and 8:1.

### Lacquer Film Capacitors—Stripped Type

One method developed in the Bell Telephone Laboratories involves forming the insulating film on a supporting base, upon which it is carried through the metallizing and slitting steps. Fig. 1 illustrates the method schematically. A suitable supporting base such as a paper sheet is first coated with a "parting layer." Lacquer which is to serve as the dielectric is then laid down in the requisite thickness and is in turn metallized. In the example shown, a margin is left at both edges. The slitting indicated in the figure shows division of the build-up into two equal sections. The edges are also trimmed to remove any beading or other irregularity in the lacquer which sometimes occurs near the edges. The next step consists of stripping the dielectric layer with its metal electrode from the supporting base and parting layer. This leaves only the capacitor winding operation in which the fragile film must be handled in self-supporting form.

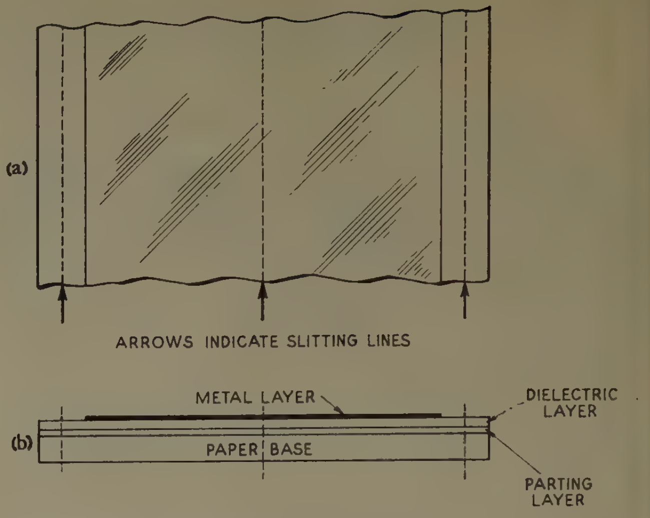


Fig. 1—Two views of build-up for construction of metallized lacquer film strips.

One process of stripping the metallized film from the base is illustrated in Figs. 2 and 3. Fig. 2 is a schematic drawing of the stripping apparatus. To start the process, a roll of the supporting sheet, bearing the parting layer and the metallized dielectric sheet, is placed on the upper shaft. The two other shafts carry empty arbors at

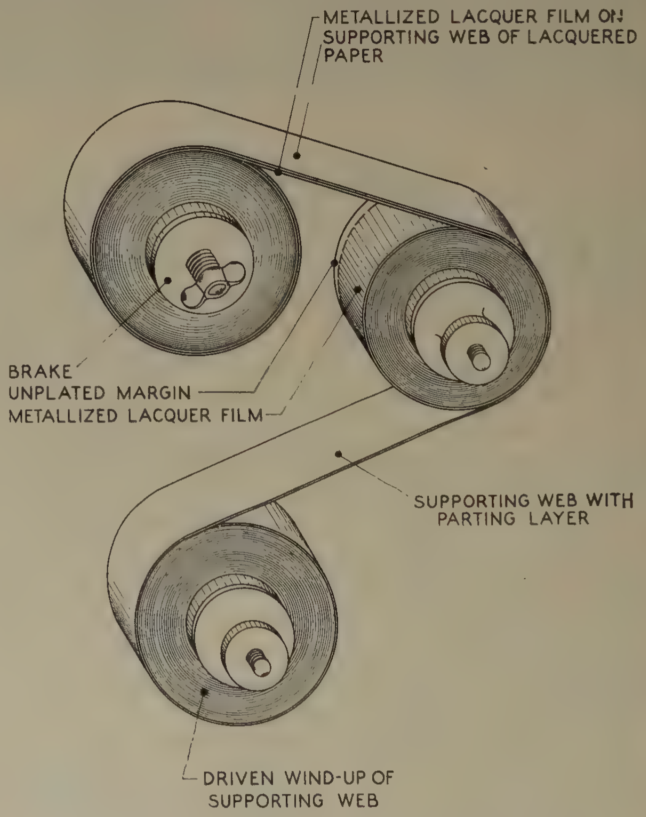

METALLIZED LACQUER FILM ON SUPPORTING WEB OF LACQUERED PAPER
BRAKE
UNPLATED MARGIN
METALLIZED LACQUER FILM
SUPPORTING WEB WITH PARTING LAYER
DRIVEN WIND-UP OF SUPPORTING WEB

Fig. 2—Method of stripping lacquer film from base.

this stage. The sheet is threaded around these arbors as shown, with the metallized side next to the middle arbor. After the apparatus is threaded, a piece of scotch tape is used to start the metallized lacquer feeding onto the central arbor. As the apparatus runs, the paper with parting layer is taken up on the lower arbor, and the metallized lacquer film winds up on the central arbor. Fig. 3 is a blown up cross section of this process.

As the supporting base, ordinary capacitor paper has been found satisfactory. It is obvious that the electrical properties of the base and parting layer are unimportant, since they form no part of the ultimate capacitor. The parting layer should be a material which is not attacked appreciably by the solvent used in applying the dielectric layer; otherwise stripping will not be successful. One suitable combination is polystyrene applied from benzene solution for the parting layer, and cellulose acetate applied from a suitable solvent for the dielectric layer. The thickness of the parting layer is relatively unimportant as long as complete coverage of the base is achieved. In fact, if one uses a base from which the dielectric layer will strip readily, the parting layer can be dispensed with. The dielectric layer must be carefully controlled in thickness and uniformity, since it is to form the dielectric of the capacitor. Within the limits in which the stripped film can be handled, the value of thickness is adjusted to that required to withstand the capacitor working voltage. While most of the experimental work to date has been done on dielectric films about 0.1 mil thick, some films as thin as 0.04 mils have been produced.

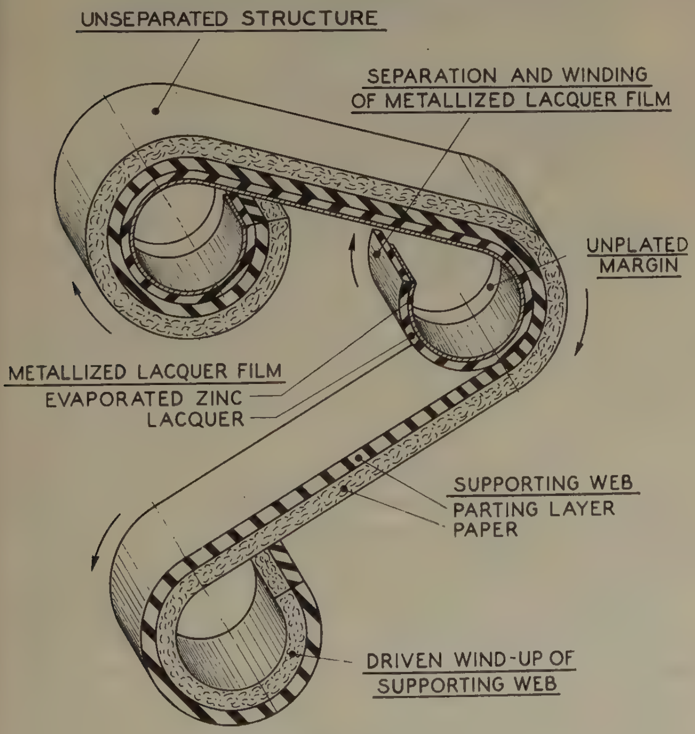


Fig. 3—Blown-up illustration of stripping process.

A roller-coater has been used to apply the parting layer and the dielectric layer. Both the lacquering and metallizing processes are described in previous publications production of metallized paper.[1,2]

Assuming 0.1 mil film, and using (1), a volume factor of $V/C=0.192$ cc/mf is obtained, which is $13\frac{1}{2}$ per cent that of the smallest available metallized paper capacitor.

Fig. 4 is a photograph showing steps in the miniaturization of capacitors. All units illustrated have a capacitance of 2 mf. At the top is a unit made with 2 layers of 0.3 mil paper and aluminum foil impregnated with stabilized chlorinated naphthalene. The middle figure is a metallized paper capacitor made with a single layer of 0.3 mil paper impregnated with a hydrocarbon wax. At the bottom is a unit made according to the present description, using 0.1 mil metallized film.

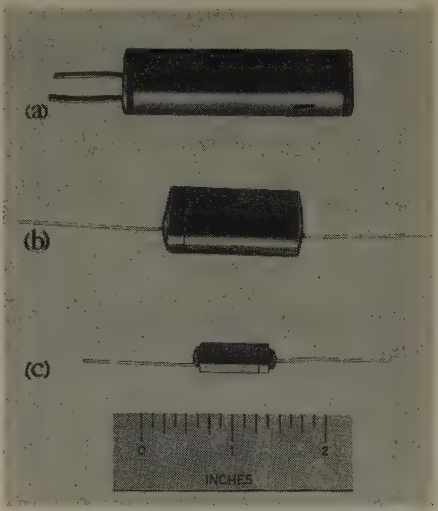


Fig. 4—Steps in miniaturization of 2 mf capacitor units. (a) Standard paper-foil capacitor unit; two layers of 0.3 mil paper. (b) Metallized paper capacitor unit; one layer 0.3 mil paper. (c) Experimental lacquer film capacitor.

The construction and processing of lacquer film capacitors will not be described, since they are modifications of those for metallized paper capacitors, which have been described elsewhere.[1,3]

Lacquer film capacitors are "self-healing" as in the case of metallized paper capacitors. Life tests made at 100 volts dc and 120 degrees F. show performance comparable with that of 0.3 mil metallized paper capacitors tested at 250 volts dc. Fig. 5 (next page) shows average insulation resistance values of a group of 0.4 microfarad lacquer film capacitors employing 0.1 mil dielectric as a function of time on test. A satisfactory stability is shown over the test period of 2,000 hours. During this test, a counter circuit in series with the samples detected only a small number of "self-healings." On a similar test at 80 volts dc, no "self-healings" were detected. These results suggest that such capacitors could be rated conservatively at 50 volts for applications where no "self-healings" are permissible, or somewhat higher where such "self-healings" can be tolerated during service.

Power factor of the units, and variations of power factor and insulation resistance with test conditions are typical of the material used in the film. At sufficiently high frequency, of course, a series resistance effect—due to the thin metallic electrodes—becomes significant, and this is governed by the thickness of the metal film, the width and thickness of the capacitor strip, and the dielectric constant of the film. The applicable relationship is derived in the Appendix.

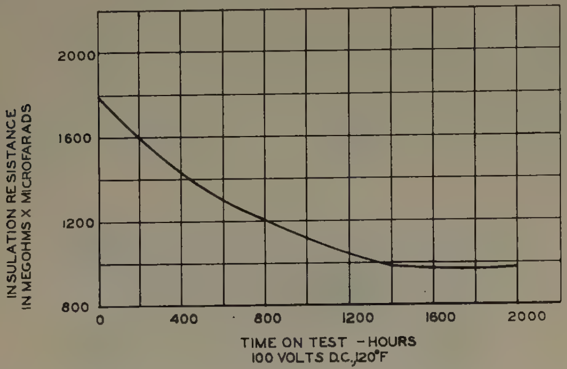


Fig. 5—Variation of insulation resistance with time on life test for experimental stripped lacquer film capacitors.

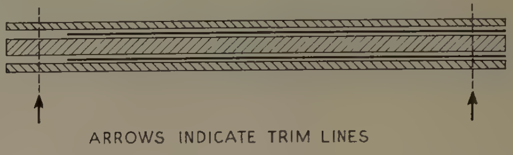
### Lacquer Film Capacitors—Supported Film Type

The method described above applies when one has considerable latitude in the selection of the lacquer film and can choose the dielectric as much for mechanical strength as for excellence of electrical properties. The present section deals with cases where one wishes miniature capacitors with unusually good electrical properties and where available dielectrics with these properties do not lend themselves to the above construction. As examples, where low voltages are involved, one would like to replace conventional mica and polystyrene film capacitors with more compact components. Metallized polystyrene sheet suggests itself, but polystyrene film of the order of 0.1 mil is much too fragile to handle even by the above methods. The thinnest self-supporting polystyrene film which has been available in this country in the past is 0.6 mil thick. In Europe commercial 0.4 mil film has been produced for some time, and this has just recently become available from a domestic source. Even at these thicknesses, the film is difficult to handle through the metallizing and slitting processes although still much too thick to use in miniature capacitors.

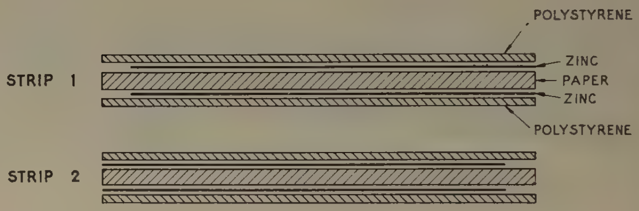
One version of the lacquer film capacitor makes possible the use of very thin polystyrene film. In this version, the film is not stripped from the base, but the latter is wound in with the film. The structure of a single strip is illustrated in Fig. 6. Several strips can be made on one supporting base and then slit to final width.

Paper or other supporting base is first metallized on both sides, leaving an unmetallized margin at one edge. The strip is then lacquered on both sides with a lacquer consisting of polystyrene dissolved in a suitable solvent. Trimming eliminates nonuniform lacquer areas which are likely to occur near the edge of the sheet, and exposes a clean metal edge for electrical contact.

In forming the capacitor, two such strips are wound together as illustrated in the lower part of the figure. When the resulting winding has terminal blocks attached to the ends by metal-spraying, Schooping, or other suitable means, it is obvious that the supporting strip is not in the electrical field and one has a metallized polystyrene film capacitor. In practice, the properties of these capacitors fall slightly short of the properties of the polystyrene dielectric used, owing to electrical fringing at the electrode edge.



CROSS-SECTION OF CAPACITOR STRIP BEFORE TRIMMING.



LAY-UP OF CAPACITOR STRIPS FOR WINDING

Fig. 6—Construction of capacitor strip and capacitors for making high quality capacitors from fragile materials.

One can, of course, form a capacitor if only one side of each sheet is lacquered, but for a given thickness of dielectric, better results are obtained by dividing the requisite thickness into two equal parts. If paper is used as the supporting base, there will be small air spaces between the sheets of dielectric, which, if desired, can be filled with a high quality dielectric wax or oil.

The necessity of leaving in the support when fragile materials such as polystyrene are used penalizes this type of capacitor from the size standpoint, as compared with the stripped lacquer film type. But experimental capacitors made in this way are significantly smaller than high quality capacitors made by any other method known to the writers. Fig. 7 (opposite) shows the size comparison between a polystyrene capacitor made with 1 mil polystyrene sheet, a mica capacitor, and a polystyrene lacquer film capacitor made in accordance with the present description. This illustration does not portray the limiting potentiality of the method, since this particular experimental lacquer film capacitor was constructed for operation at 150 volts, and for lower voltages the capacitors will be correspondingly smaller.

Electrical properties which have been obtained in polystyrene lacquer film capacitors are:

| | |
|---|---|
| Insulation resistance (1 minute electrification) | 27 degrees C. 166,000 meg. mf<br>65 degrees C. 31,000 meg. mf |
| Capacitance aging (24 cycles, room temp. to 65 degrees C.) | 0.07 per cent |
| Temp. coef. of capacitance | −78 ppm/degrees C. |
| Power factor | 1,000∼0.015 per cent<br>10,000∼0.06 per cent<br>80,000∼0.40 per cent. |

The decreasing power factor with increasing frequency is believed in this case to result from inadequate contact between the Schooped terminal block and metal film, a situation which has since been improved. This can be further improved by increasing the amount of metal and making the capacitor strip narrower, as is more apparent from the development in the Appendix.

Insulation resistance values and stability such as listed above depend upon careful processing of the wound units.

Too much "self-healing" in polystyrene capacitors leads to lowering the insulation resistance. However, if kept within bounds, "self-healing" is an important feature of this type of capacitor. In the structure described, "self-healing" is minimized by the use of a 2-layer dielectric.

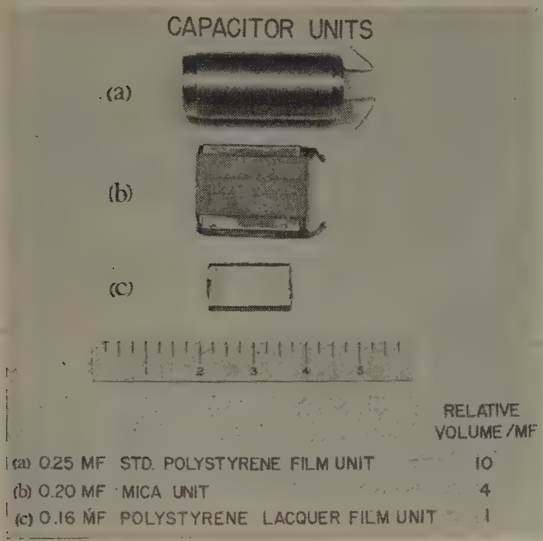

CAPACITOR UNITS
(a)
(b)
(C)
1
2
3
4
5
RELATIVE VOLUME/MF
(a) 0.25 MF STD. POLYSTYRENE FILM UNIT 10
(b) 0.20 MF MICA UNIT 4
(c) 0.16 MF POLYSTYRENE LACQUER FILM UNIT 1

Fig. 7—Comparison of several types of high quality capacitors.

## Other Circumstances Where Use of a "Supported" Film May Be Desirable

Lacquer film capacitors with the supporting strip left in may be used to accomplish miniaturization, even where the excellent properties of polystyrene or like materials are not required. In such instances one may use other dielectrics, and may or may not be concerned with shielding the supporting strip from the field. For this reason, a wider choice of constructions is allowable, some of which are illustrated in Fig. 8. Such constructions are easier to handle and require fewer operations than is the case with stripped lacquer films.

When the supporting strip is wound into the unit, the capacitor will theoretically be larger than for the alternate construction using stripped lacquer film. However, when manufacturing limitations are taken into account, there are likely to be circumstances where the use of the supporting film does not in fact add to the capacitor size. These circumstances are clarified in the following paragraphs.

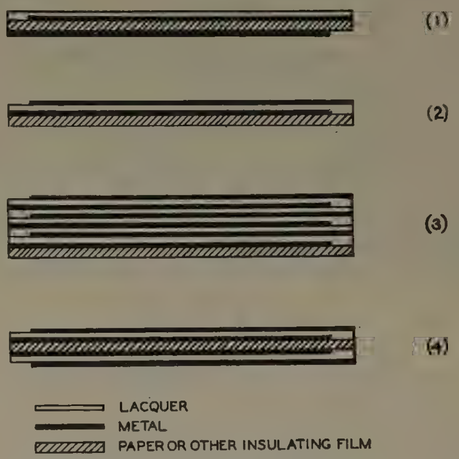


Fig. 8—Some further possible constructions of capacitor strip where support is to be wound in with dielectric strip.

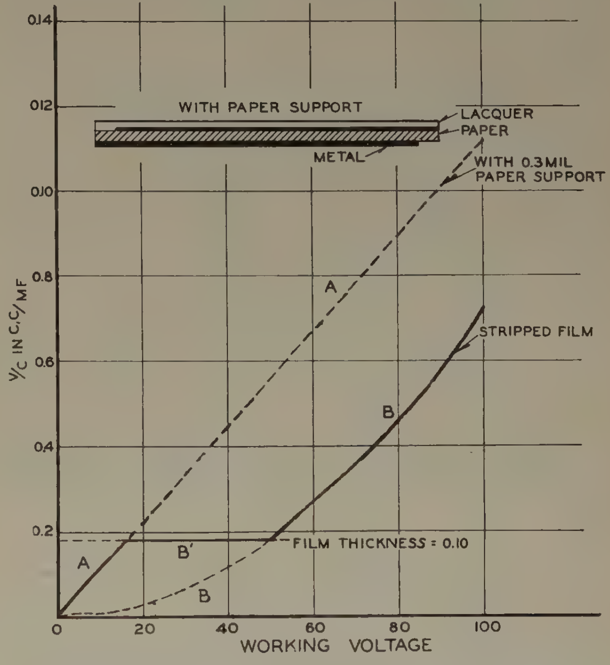


Fig. 9—Calculated space factors for stripped metallized lacquer film capacitors compared with those of supported metallized lacquer film capacitors.

Fig. 9 shows calculated space factors for examples of the two types of metallized lacquer film capacitors as functions of working voltage based on a thickness of 0.002 mils/volt.[6] Curve *B* applies to the stripped lacquer film type. It is assumed that (1) applies and that cellulose acetate of dielectric constant 3.8 is employed. As the working voltage decreases, the required thickness of dielectric film, and hence the volume, becomes smaller.

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[6] A thickness found adequate in stripped lacquer film capacitors. See previous sections.

However, one reaches a point ultimately, not well defined at present, where it is not possible to strip and wind the extremely thin film. This presents a lower limit in size for this type of capacitor, and while the theoretical curve (dotted) continues to descend, the curve of practical accomplishment becomes a horizontal line $B'$ (full). Let us assume that this stage is reached at a thickness of 0.10 mils, which appears to be about the actual lower limit permitted by current techniques. This would mean a lower volume limit of 0.18 cc/mf.

Compare this with curve $A$, which is the theoretical relationship for a lacquer film capacitor of the supported film type employing 0.3 mil paper as the support. This curve is based on the equation:

$$V/C = 72.9\,\frac{d_1 + d_2}{\dfrac{e_1}{d_1} + \dfrac{e_2}{d_2}}, \qquad (2)$$

where $d$ is thickness and $e$ dielectric constant and the subscripts 1 and 2 denote supporting layer and lacquer film. It is assumed that the supporting paper ($d_1 = 0.3$ mil) is impregnated with hydrocarbon wax, giving $e_1 = 4.0$. The dielectric constant of the lacquer is assumed to be 3.8.

If one follows curve $A$ down to the origin, it is, of course, above the theoretical curve $B$ all the way. There is, however, no reason to believe that there is any practical limit to the thinness of the lacquer that can be used. This curve $A$ will therefore cut through the curve $B'$, for practical accomplishment of the other type; and for values of voltage below this intersection, a smaller capacitor can be made if the support is left in. Based on the assumptions made in this section, including a limiting value of 0.10 mil for stripped film, the cross-over point is 16 volts. The full line of Fig. 9 is drawn to represent minimum size when one has the choice between the two types of capacitors. If the limiting thickness is lower, the cross-over point will correspond to a lower voltage.

It should be pointed out that these considerations are based on idealized structures and do not take into consideration the influence of the irregular surface of paper or other support. A closer approximation to the idealized structure would result from use of a supporting film on a plastic such as Mylar.

A further consideration is that the relative simplicity of manufacture of a capacitor with the support left in might favor this type even in the region somewhat above the cross-over point of Fig. 9.

## APPENDIX

### *Effective Series-Resistance of Metallized Capacitors*

A design factor which must be observed in the construction of metallized capacitors, is the effective series-resistance imposed by the thin metal film. This is normally unimportant at low frequencies, but becomes a factor at the higher frequencies. If all other factors, including width of capacitor strip, remain constant, the effective series-resistance increases as the dielectric thickness is decreased. It therefore becomes important to be able to estimate the effective series-resistance when extremely thin dielectric films are used as described above.

It is convenient to consider the effective series-resistance in a capacitor having a lossless dielectric. This provides one with the limiting electrical impedance due to the electrodes alone. Knowledge of the effective series-resistance allows calculation of the limiting power factor, or $Q$ at high frequencies, where the loss is for practical purposes all in the electrodes.

The electrode-limited value of $Q$ is given by $1/\omega C R_e$ where $C$ is the capacitance and $R_e$ the effective series-resistance of the electrode system. $Q$ can further be defined as $1/\tan\delta$, where $\delta$ is the loss angle. Also for values of $Q$ above 10, the power factor can be taken as the reciprocal of $Q$.

The effective series-resistance of the electrodes is defined as the series-lumped-resistance which would dissipate the same power as the electrodes. If $I$ is the current flowing in the capacitor ($\omega CE$), the electrode loss is $I^2 R_e$.

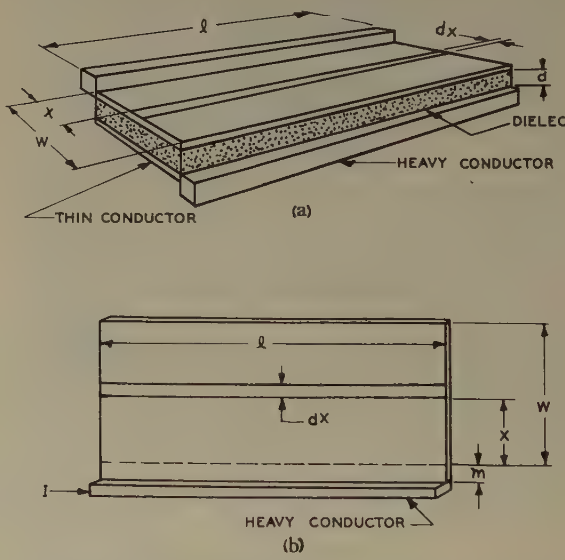

Fig. 10—Schematic representation of a metallized paper or "extended foil" capacitor. (a) Both electrodes, excluding margin area. (b) One electrode, including margin area. The heavy conductor is a hypothetical bar representing contact between the electrode and a terminal block.

Fig. 10(a) is a schematic representation of a metallized dielectric capacitor shown as a parallel plate structure. Although contact is not normally made at all points along the edge of the metal layer, but only twice at each turn of the winding, probably no serious error results from assumption of continuous contact, indicated by the heavy bus-bar conductor in the figure.

It is convenient to speak of the resistivity of the electrode in terms of ohms per square, which is the resistance between opposite edges of any square. If this has a value of $r$, then the resistance of any rectangle is $ra/b$ ohms, where $a$ is the length and $b$ the width of the electrical path.

The development below assumes $R_e$ is small compared with capacitor impedance, $1/\omega C$, otherwise uniform current distribution will not obtain. This assumption will normally be valid at moderate frequencies.

If $I$ is the current flowing in the capacitor of Fig. 10, $l$ the length of foil, and $w$ the width, the current flowing past any line distance $x$ from the terminal edge is $(w-x/w)\ I$. The resistance in the direction of current flow of an elementary strip $dx$ wide is $rdx/l$.

The dissipation ($I^2R$ loss) in the element $dx$ is

$$dD = \frac{(w-x)^2 I^2 r}{w^2 l}\,dx,$$

and dissipation over the whole area of one electrode is,

$$\begin{aligned} D &= \int_0^w \frac{(w-x)^2}{w^2}\,\frac{I^2 r}{l}\,dx \\ &= \left.\frac{I^2 r}{w^2 l}\,\frac{(w-x)^3}{3}\right]_0^w \\ &= \frac{I^2 r w}{3l}\,. \end{aligned}$$

The dissipation in both electrodes is twice this value, or

$$D = \frac{2I^2 r w}{3l},$$

and the effective series-resistance

$$R_e = \frac{D}{I^2} = \frac{2rw}{3l}\,.$$

If it is desired to express $R_e$ as a function of dielectric thickness, $d$, we first write the expression for capacitance of a parallel plate capacitor.

$$C = k\,\frac{A}{d}\,e$$

where $A$ is the area of one electrode, and $e$ is the dielectric constant of the dielectric. If $C$ is in microfarads, and the dimensions in centimeters, $k = 0.0885 \times 10^{-6}$. But, for a wound capacitor, which is the form that metallized capacitors usually take in practice, both sides of each electrode are effective, and the capacitance is doubled. Thus,

$$C = 2k\,\frac{A}{d}\,e, = 2k\,\frac{wle}{d},$$

hence,

$$l = \frac{Cd}{2kwe},$$

and therefore,

$$R_e = \frac{4k}{3}\,\frac{rw^2e}{Cd}\,.$$

Thus, for a given dielectric ($e$=constant) and a given capacitance, the effective series-resistance is inversely proportional to the dielectric thickness if the width is held constant. However, it varies directly with the square of the width, and we will usually want to use smaller widths when thin lacquer films are employed.

*Correction for Margins*

In the above, no account was taken of margins' through which the current must pass to reach the active capacitor. This will obviously add something to the effective series resistance.

If $m$ is the width of margin, as shown in Fig. 10(b) which depicts one electrode, the dissipation in the margin is $I^2\,rm/l$, which must be added to the dissipation expressed above.

The total dissipation in the two electrodes becomes

$$D = \frac{2I^2 r}{l}\left(\frac{w}{3} + m\right)$$

and $R_e$ corrected for the loss in margins is

$$\begin{aligned} R_e &= \frac{2r}{l}\left(\frac{w}{3} + m\right) \\ &= \frac{2rw}{l}\left(\frac{1}{3} + p\right), \end{aligned}$$

where $p$ is defined as the ratio of margin to effective width $= m/w$. Following through the rest of the derivation as before,

$$R_e = \frac{4k}{3}\,\frac{rw^2e}{Cd}\,(1 + 3p).$$

These equations, compared with those which did not involve the margin, show that one needs only multiply the uncorrected expressions for $D$ and $R_e$ by a factor $(1+3p)$, in order to include the loss in the margins.

All equations in this Appendix naturally apply equally well to paper-foil capacitors of the "extended foil" type.

# Correction

P. D. Strum, author of the paper, "Some Aspects of Mixer Crystal Performance," which appeared on pages 875–889 of the July, 1953 issue of the PROCEEDINGS OF THE I.R.E., has called attention to several minor inaccuracies pointed out to him by private communication from W. L. Pritchard of Raytheon Manufacturing Company, and S. Deutsch of Polytechnic Research and Development Company. Mr. Pritchard indicated that Fig. 4 seemed to be inaccurate for low values of conversion loss, while Fig. 11 appeared to be inaccurate inasmuch as the relation between $t_m$ and $t_x$ should be linear, and the relation between nonoptimum source conductance and increase in loss was misstated. Mr. Deutsch indicated apparent errors of a few per cent in the calculated values of IF resistance in Table I.

The equation plotted in Fig. 4 is

$$SWR = (L + 1)/(L - 1).$$

Examination of the figure shows that this equation has been accurately followed for values greater than about 3 db, whereas at 2 db the plotted curve is approximately 0.5 unit too high. Such an error undoubtedly resulted from transcribing the original data to the final curve.

In Table I the calculated values have been shown to three significant places, whereas the computation accuracy did not actually warrant this. Mr. Deutsch informs that from his detailed calculations the agreement between calculated and measured values in certain cases is better than that shown in the table.

The equation that should govern the relationships in Fig. 11 is

$$t_m = 1 + (1 - 1/L_1 - 1/L_2 - \cdots - 1/L_n)(t_x - 1),$$

where $t_m$ and $t_x$ are as defined in the paper.[1] The losses in the equation, however, refer to conversion from the intermediate frequency to various sidebands as follows:

1. $L_1$ is the fundamental conversion loss between the IF and the signal terminals.
2. $L_2$ is the fundamental conversion loss between the IF and the image-frequency terminals.
3. $L_3$ is the second-harmonic conversion loss pertaining to conversion from the IF to the sum-frequency terminals. The sum frequency is the upper or lower sideband of the second harmonic of the local-oscillator frequency, depending upon whether the original signal is above or below the local-oscillator frequency.
4. $L_4$ is the conversion loss to the other sideband of the second harmonic of the local-oscillator frequency.
5. And so forth.

These losses include the conversion loss from the IF terminals to the resistive antenna terminals, and to any internal dissipative load that may match a particular sideband.

A corrected Fig. 11, below, is shown with the original curves given in dashed lines to indicate the discrepancies. It is seen that the straight lines representing the new curves and the old curves become tangent at $t_x = 1$. The original curves were computed by the laborious process of assigning a noise temperature to the individual conductances in the equivalent circuit and calculating a noise temperature for the output impedance. It seems that the calculations were in error, however. In addition to the computational errors in Fig. 11(b) the horizontal limit line was labeled 0 db. Instead, this limit line should be labeled 3 db, because 3 db is the minimum loss that can occur in a mixer with matched image terminals.

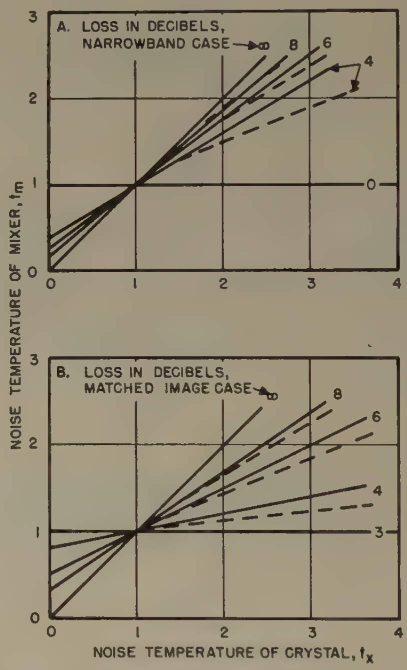

Fig. 11—Mixer noise temperature vs crystal noise temperature and conversion loss. (Solid-line curves are corrected; dashed-line curves are originals.)

On pages 887 and 888, values from Fig. 11 were used in making computations on optimum receiver design. It should be pointed out that the errors in these computations were small because the loss and noise temperature values were in the region where the divergence between the two sets of curves was small. Therefore, none of the conclusions regarding optimum intermediate frequency and optimum receiver design require modification as a result of inaccuracies in the curves.

In the fourth paragraph of Part VI, it is stated that a deviation from the optimum source conductance would cause an increase in over-all loss that could be determined by mismatch loss calculations. This is true when the output is terminated or when the conversion loss is large. When the conversion loss is small, this is not the case. Instead, when the source conductance is other than optimum, the minimum available loss is given by the expression

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[1] Mr. Pritchard suggested the forms $t_m = 1 + [(L-1)/L][t_x - 1]$ for the narrowband case, and $t_m = 1 + [(L-2)/L][t_x - 1]$ for the matched image case. However, the general form given here is preferred.

$$L_{\min} = \frac{(L^2 - 1)(\gamma_r/\gamma_I + \gamma_I/\gamma_r) + 2(L^2 + 1)}{4L},$$

where $L$ is the conversion loss. It should be noted that $\gamma_r/\gamma_I$ is not the *SWR*.

A few other errors also escaped the author's attention in proofreading the article. On page 879, just above (18), reference to Fig. 4 should be to Fig. 3; page 881, just above Fig. 6, reference to Fig. 6 should be to Fig. 7; on the next line, reference to Fig. 7 should be to Fig. 8; same page, third line from end, reference to Fig. 6 should be to Fig. 7; page 882, seventh line, second paragraph, reference to Fig. 6 should be to Fig. 5; page 886, sixth line, second paragraph, Beringer's name was misspelled; page 889, in the acknowledgement, Pritchard's name was misspelled.

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# Correspondence

## On Reciprocal Inductance*

A very useful and basic parameter in circuit theory remains conspicuously nameless. This parameter is commonly referred to as the reciprocal inductance ($\Gamma = L^{-1}$) for lack of a better name. It seems to this writer that the same notions that have led us to the adoption of the term "elastance" for the reciprocal capacitance can lead equally smoothly to the adoption of the name "inertiance" for the reciprocal inductance.

An argument to establish the plausibility of the conceptual analogy involved might start with the expression:

$$T = \tfrac{1}{2}\Gamma\psi^2$$

for the magnetic stored energy, $T$, in terms of $\Gamma$ and the flux linkages, $\psi$, pertinent to the inductive element. It is natural to associate $T$ with kinetic energy in mechanics; $\psi$ could then be considered the magnetic analog of velocity, and $\Gamma$ the analog of mass, or inertia. The electric current, $i = \Gamma\psi$, becomes the analog of momentum. If $\Gamma$ is constant, then

$$\frac{di}{dt} = \Gamma\frac{d\psi}{dt},$$

which can be interpreted as showing $\Gamma$ to represent the inertia of the magnetic medium to any change in the flux linkages arising from a change in the electric current. Thus, a well-known physical principle may be stated in the form:

A magnetic element persists in its state of rest ($\psi = 0$) or constant value of flux linkages ($d\psi/dt = 0$) unless compelled by an external agency ($di/dt \neq 0$) to change that state.

We recognize $d\psi/dt$ as the transformer voltage and here as the analog of acceleration.

We might remark in passing that the inverted $L$, $\Gamma$, representing, in current use, the reciprocal inductance, will be found to fit the suggested name nicely if interpreted as being the capital gamma, instead.

This writer cannot recall coming across the name "inertiance" to describe the reciprocal inductance. If this name has already been suggested by anyone else, then we would like to second the motion. If not, we shall be only too happy to have christened "inertiance."

E. J. Baghdady
Research Lab. of Electronics
Mass. Inst. of Tech.
Cambridge, Mass.

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* Received by the IRE. September 27, 1954.

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## The Wien Bridge as a Phase Shifter*

The two rc arms of the Wien bridge provide a simple phase shifter which seems to have been neglected in the past. However, it has proven very convenient for precise gain and phase measurements on special purpose transformers at UTC. In the circuit of Fig. 1, it is easily found that

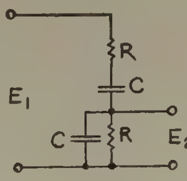

Fig. 1

$$\frac{E_2}{E_1} = \frac{\cos\theta}{3}\angle\theta,$$

where

$$\theta = \arctan\left[\frac{\dfrac{1}{R\omega C} - R\omega C}{3}\right].$$

Thus, a considerable phase shift may be achieved in the vicinity of zero without much amplitude change. For $|\theta| < 8.1°$, $|E_2/E_1|$ is within 1 per cent of the value at $\theta = 0$. Of course, the amplitude change may be of no importance, but what is in mind here is the independent adjustment of phase and amplitude for the purpose of comparing two voltages: in other words, an ac potentiometer. In such a device a null indication could be obtained by inverting one of the signals and mixing the two in a resistive mixer. However, the Wien bridge itself may conveniently be used as a mixer, as shown in Fig. 2. In this case, it is easily shown that a null output is obtained for

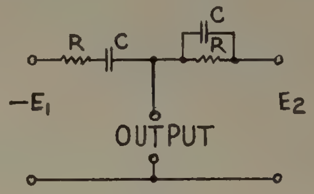

Fig. 2

$$\frac{E_2}{E_1} = \frac{\cos\theta}{2}\angle\theta,$$

where

$$\theta = \arctan\left[\frac{\dfrac{1}{R\omega C} - R\omega C}{2}\right].$$

Thus, the variation of amplitude with required phase shift is the same as before, a cosine law.

To refine the method further, it would be highly desirable to completely eliminate the amplitude variation, and thus permit much larger phase shifts to be accommodated. This may be done by using specially shaped, unequal condenser plates.

Fig. 3 (following page) shows the circuit with unequal condensers, and with the unavoidable stray capacitances $C_3$ and $C_4$ ($C_4$ is usually the more serious of the two). Solving the circuit for the condition of zero output, we find:

$$\frac{E_1}{E_2} = \frac{C_2}{C_1} + \left(1 + \frac{C_4}{C_1}\right)\left(\frac{1 + R^2\omega^2 C_2 C_3}{1 + R^2\omega^2 C_3^2}\right) + j\left(\frac{-1}{R\omega C_1} + \frac{R\omega(C_2 - C_3)}{1 + R^2\omega^2 C_3^2}\right). \quad (1)$$

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* Received by the IRE, July 7, 1954. Permission to release this material granted by the United Transformer Co., New York, N. Y.

At zero phase shift, let

$C_1 = C_2 = C_0$ and $|E_1/E_2| = k$.

Therefore:

$$1 + \left(1 + \frac{C_4}{C_0}\right)\left(\frac{1 + R^2\omega^2 C_0 C_3}{1 + R^2\omega^2 C_3^2}\right) = k. \qquad (2)$$

$$\frac{-1}{R\omega C_0} + \frac{R\omega(C_0 - C_3)}{1 + R^2\omega^2 C_3^2} = 0. \qquad (3)$$

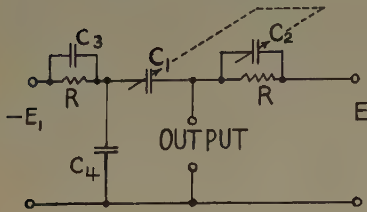

Fig. 3

Eq. (3) may be solved for $R\omega$ in terms of $C_0$ and $C_3$:

$$R\omega = \frac{1}{\sqrt{C_0^2 - C_0 C_3 - C_3^2}}. \qquad (4)$$

To obtain constant amplitude, it is only necessary to set the real part of (1) equal to $k \cos \theta$ and the imaginary part equal to $k \sin \theta$ (note that $\theta$ is now the angle of $E_1/E_2$, while in the simpler cases mentioned above it was the angle of $E_2/E_1$):

$$k \cos \theta = \frac{C_2}{C_1} + \left(1 + \frac{C_4}{C_1}\right)\left(\frac{1 + R^2\omega^2 C_2 C_3}{1 + R^2\omega^2 C_3^2}\right). \qquad (5)$$

$$k \sin \theta = \frac{-1}{R\omega C_1} + \frac{R\omega(C_2 - C_3)}{1 + R^2\omega^2 C_3^2}. \qquad (6)$$

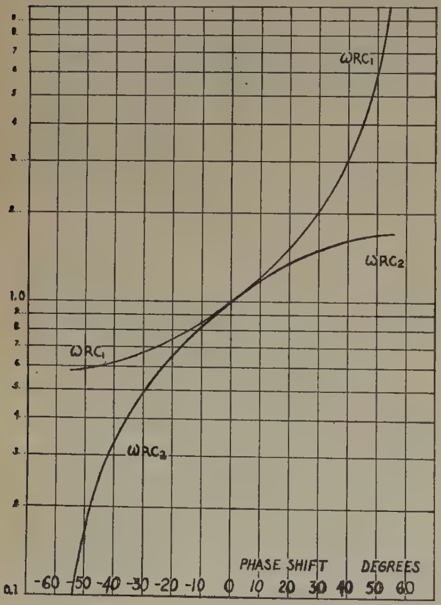

Fig. 4

With given values of $C_0$, $C_3$ and $C_4$, $R\omega$ is found from (4) (note that frequency variations can be accommodated by varying $R$), and (5) and (6) can be solved for $C_1$ and $C_2$ as functions of $\theta$. For the case $C_3 = C_4 = 0$, this results in the following:

$$R\omega C_1 = \frac{\sin \theta + \sqrt{\sin^2 \theta + 2 \cos \theta - 1}}{2 \cos \theta - 1}. \qquad (7)$$

$$R\omega C_2 = \sin \theta + \sqrt{\sin^2 \theta + 2 \cos \theta - 1}. \qquad (8)$$

Eqs. (7) and (8) are plotted as shown in Fig. 4.

In conclusion, condenser plates cut as given by (5) and (6), which for the case of zero stray capacitance are shown by the curves, permit a phase-shifting mixer of the Wien bridge type with a constant amplitude characteristic. A somewhat similar analysis can be carried through for a simple transmission phase shifter of the type shown in Fig. 1.

JOSEPH M. DIAMOND
United Transformer Company
New York, N. Y.

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## Expression for the "$\alpha$ Cut-Off" Frequency in Junction Transistors*

Various authors have obtained a theoretical expression for the "$\alpha$ cut-off" frequency in junction transistors. This has been determined by considering frequency variations in the transport factor $\beta$ and assuming the injection efficiency $\gamma$ to be independent of frequency in the expression

$$\alpha = \alpha_i \beta \gamma, \qquad (1)$$

where $\alpha_i$ is taken as 1 for simple junction transistors. Neglecting surface recombination, Shockley, Sparks, and Teal[1] have derived an expression of the form

$$\beta = \operatorname{sech} \left[W^2/L_m^2 + j\omega W^2/D_m\right], \qquad (2)$$

where $\omega$ is the angular frequency, $D_m$ the diffusion constant for minority carriers in the base region of width $W$, and the diffusion length

$$L_m = (D_m \tau_m)^{1/2} \qquad (3)$$

$\tau_m$ being the minority carrier lifetime in the base.

The current multiplication factor $\alpha$ is then 3 db down from its low frequency value at an angular frequency $\omega_c$ such that

$$|\beta/\beta_0|^2 = \tfrac{1}{2}, \qquad (4)$$

where $\beta_0$ is the value of $\beta$ at $\omega = 0$. Eq. (4) is difficult to solve exactly for $\omega_c$ and hence various authors have made mathematical approximations using the assumption

$$W/L_m \to 0 \qquad (5)$$

yielding the result

$$\omega_c = \kappa D_m/W^2. \qquad (6)$$

The value of $\kappa$ has been given variously as 2,[1,2] which is an incorrect solution, and as 2.43,[3] which is correct for the case of the approximation (5). Both of these values have been used by various authors.[4–6]

Assumption (5) is not a good approximation for many transistors and we indicate a method of solution for nonzero values of $W/L_m$, in which case $\kappa$ becomes a slowly varying function of $W/L_m$. For a given transistor, an estimate of the value of $W/L_m$ may be made from the measured value of $\alpha$ using (1) and (2) for $\omega = 0$.

Using tables and charts of cosh $(x+iq)$ by Kennelly,[7] the solution of (4) is obtained by setting

$$\cosh \left[W^2/L_m^2 + j\omega W^2/D_m\right]^{1/2} = \cosh (u + jv), \qquad (7)$$

whence

$$|1/\beta|^2 = |\cosh (u + jv)|^2 = 2/\beta_0^2, \qquad (8)$$

and we have

$$W^2/L_m^2 = u^2 - v^2 \qquad (9)$$

$$\omega_c W^2/D_m = 2uv. \qquad (10)$$

One may then choose the value of $W/L_m$, and obtain $u$ and $v$ from Kennelly's charts of $\cosh(u+jv)$ against $r/\psi$ where $r = 1 \cdot 414/\beta_0$. The expression for $\omega_c$ is then given by (10). Some values are listed in Table I.

TABLE I

Values of $\kappa$ for given $W/L_m$

| $W/L_m$ | $\kappa$ | $\beta_0 = \operatorname{sech} W/L_m$ |
|---|---|---|
| 0.35 | 2.56 | 0.942 |
| 0.30 | 2.53 | 0.956 |
| 0.25 | 2.50 | 0.970 |
| 0.20 | 2.47 | 0.983 |
| 0.10 | 2.45 | 0.995 |
| 0 | 2.43 | 1.000 |

A definite value of $\kappa$ is important in the comparison of experimental values of $\omega_c$ with theoretical predictions for various operating points. As pointed out by Early,[8] the value of base width $W$ is appreciably dependent on collector voltage $V_c$. Using Shockley's[9] expression for barrier width in a step-junction transistor, we can derive

$$\omega_c = \kappa D_m/\left[W_0 - \delta V_c^{1/2}\right]^2, \qquad (11)$$

where $W_0$ is effective base width for zero collector voltage and

$$\delta^2 = K/600\pi q n_n, \qquad (12)$$

$K$ being the dielectric constant for the semiconductor, $q$ the electronic charge, and $n_n$ the majority carrier concentration in the base region. For germanium, $\delta = 1.19 \times 10^{-4}$ cm/volt$^{1/2}$ for 1.5Ω cm $n$-type material. Hence for very thin base regions a big increase in $\omega_c$ is expected for higher collector voltages; the order of the effect is indicated in Table II, for the two $p$-$n$-$p$ germanium transistors of base resistivity 1.5Ω cm and $\beta_0$ of $0 \cdot 97$.

TABLE II

Values of $\omega_c/2\pi$ for two $p$-$n$-$p$ transistors
Ge $\rho = 1.5$ Ωcm $\beta_0 = .97$ $\kappa = 2.50$

| $W_0$ \ $V_c$ | 5 volts | 15 volts | 30 volts |
|---|---|---|---|
| 0.006 cm | 535 kc | 565 kc | 610 kc |
| 0.003 cm | 2.40 Mc | 2.71 Mc | 3.17 Mc |

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* Received by the IRE, July 15, 1954.

[1] W. Shockley, M. Sparks, and G. K. Teal, "*P-n* junction transistors," *Phys. Rev.*, vol. 83, p. 151; 1951.

[2] E. L. Steele, "Theory of alpha for *p-n-p* diffused junction transistors," PROC. I.R.E., vol. 40, pp. 1424–1428; November, 1952.

[3] R. L. Pritchard, "Frequency variations of current-amplification factor for junction transistors," PROC. I.R.E., vol. 40, pp. 1476–1481; November, 1952.

[4] C. W. Mueller and J. I. Pankove, "A *p-n-p* triode alloy junction transistor for radio-frequency amplification," *RCA Rev.*, vol. 14, p. 586; 1953.

[5] R. Kansas, "Part IV—On the high-frequency performance of transistors," PROC. I.R.E., vol. 41, pp. 1712–1714; December, 1953.

[6] J. M. Early, "Design theory of junction transistors," *Bell Sys. Tech. Jour.*, vol. 32, p. 1294; 1953.

[7] A. E. Kennelly, "Tables of Complex Hyperbolic and Circular Functions," Harvard University Press, Cambridge, Mass., 2nd ed.; 1927.

A. E. Kennelly, "Chart Atlas of Complex Hyperbolic and Circular Functions," Harvard University Press, Cambridge, Mass.; 1924.

[8] J. M. Early, "Effects of space-charge layer widening in junction transistors," PROC. I.R.E., vol. 40, pp. 1401–1406; November, 1952.

[9] W. Shockley, "The theory of *p-n* junctions in semiconductors and *p-n* junction transistors," *Bell Sys. Tech. Jour.*, vol. 28, p. 435; 1949.

These results are in qualitative agreement with experiment, in particular the prediction of greater sensitivity of $\omega_c$ to $V_c$ if $\omega_c$ is initially high. It is seen from (11) and (12) that higher resistivity material should yield higher $\omega_c$ and greater increase with increasing $V_c$.

D. Haneman
Div. of Radiophysics
CSIRO
Sydney, Australia

## Comment on "Transfer Characteristics and the Mu Factor of Picture Tubes"* Kurt Schlesinger[1]

My attention has been drawn, somewhat belatedly, to the interesting paper above.

In this paper, Dr. Schlesinger endeavors to establish by theoretical methods the form of the cathode current/grid voltage drive curve for a cathode ray tube. He obtains results which are in substantial agreement with what is observed.

Unhappily, this agreement is coincidental, and is due to the fact that two errors of opposing sense cancel each other. In brief, Dr. Schlesinger establishes his value for gamma by writing the Child's 3/2 power law and multiplying this by an additional increment of current due to the increase of cathode area when the tube is driven. However, the analysis in which he derives the law, connecting the variation of cathode area with grid drive is necessarily complicated, and involves numerous assumptions. The results he obtains are not in agreement with experiment. In my paper[2] I discussed in detail the experimental results obtained for variation of cathode area with grid drive. The method used was to project an image of a marked cathode surface onto a measuring screen. Fig. 1 shows roughly the form of curve relating the diameter of the emitting cathode to the grid drive. For a planar structure this form of curve appears to be reproduced for quite wide variations in the electrode spacings although of course the numerical values will be changed. Not by any stretch of the imagination can this curve be described as a root function in the way in which in which Dr. Schlesinger establishes from his analysis. The best average approximation appears to be a linear one shown by drawing the straight line $AB$ between the two end points of the curve.

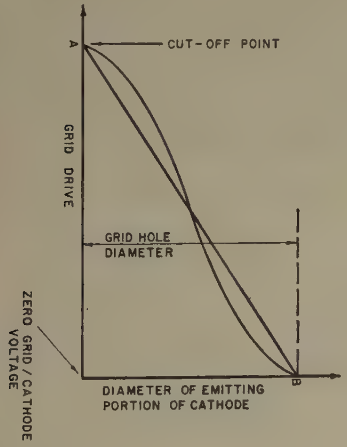

Fig. 1

Following the method of Dr. Schlesinger, we now see that the total cathode current would vary according to the 3/2 power of the grid drive (on account of Child's law), multiplied by the grid drive squared on account of the linear grid drive/cathode diameter relationship experimentally established. This yields a 7/2 power law for gamma.

The question now comes, "Why is it a fact that in most cases the observed gamma is considerably less than 7/2?" This can be explained very simply by an experiment which I performed using a small Faraday cage to explore the variation of emission density of the cathode surface. At very low grid drives this follows the expected 3/2 law, but with normal oxide cathodes running at around 760 degrees C., the center of the emitting portion of the cathode very soon becomes temperature limited. Fig. 2 shows a typical type of curve observed for the current distribution across the cathode. It is the failure of most cathodes to follow the Child's 3/2 power law which causes the value of gamma to be appreciably lower than the 7/2 obtained by the unsophisticated analysis so far given. As a further check on the accuracy of these opinions, my paper describes experiments measuring the value of gamma for very high cathode temperatures in which the 3/2 power law is followed. Gamma values of about 7/2 are then observed.

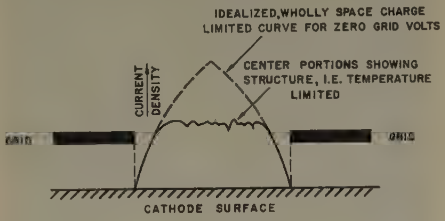
IDEALIZED, WHOLLY SPACE CHARGE LIMITED CURVE FOR ZERO GRID VOLTS
CENTER PORTIONS SHOWING STRUCTURE, I.E. TEMPERATURE LIMITED
CURRENT DENSITY
GRID
GRID
CATHODE SURFACE

Fig. 2

I think the moral from all this is interesting. It serves as a warning, if indeed this is necessary, about the tremendous complexity of theoretical studies of triode of the cathode ray tube. It might as well be realized that at the moment, the value of mathematical analysis in this region is quite limited. Inevitably one is driven into one of three corners: (1) Either making "reasonable" simplifying postulates, as Dr. Schlesinger has done, and all too frequently obtaining results which are a long way removed from practice; or (2) Endeavoring to force an analysis with all factors taken into account, which assuredly leads to such complications that the resulting formulas would be of no value, even if they could ever be found; or (3) Abandoning at a critical moment general symbols and inserting numerical values. This last process lacks elegance, and has no more generality than an experiment performed on a particular system in a laboratory.

It remains a sad fact that, at the moment, mathematics has not provided the assistance in this field which is comparable to that which it can give in, let us say, linear circuit work.

None of my remarks is intended to be an attack on mathematical methods in general, still less upon Dr. Schlesinger's high analytical ability.

Hilary Moss
Burroughs Corp.
Paoli, Pa.

## Rebuttal[3]

In his foregoing letter, Dr. Moss takes issue with the statement, derived in my paper, that the growth of the emissive diameter of the CRT-cathode closely approximates the square root of the grid drive. This law gives results that check with experience, in that it yields gamma figures around 2.4 and correct mu factors.

Dr. Moss reports that his experiments with scribed cathodes have indicated a cathode swell in linear proportion to grid drive all the way down to cutoff. This should result in an observed gamma of 3.5 which has not been found. As an explanation, it is assumed that the emission was temperature limited. This condition does not apply to commercial picture tubes.

Dr. Moss summarizes his own findings by his curve, Fig. 1, which he then interpolates by a linear function. It seems to this writer that it requires a much greater stretch of the imagination to accept that straight line than to recognize the first half of Dr. Moss' data plot as part of a root function. If this were agreed upon, it would automatically restore harmony between the work of Dr. Moss and my own. Note also that data in my paper are derived only up to, but not beyond, emission diameters of one-half the grid opening. (See my Fig. 1.)

This author sincerely appreciates the great experimental skill that went into the investigation reported by Dr. Moss, and wishes to compliment him for it. If the test was performed at a 1:1 scale, we are dealing with cathode diameters of about 25 mils, of which about one-half, including the vanishing point, is under consideration here. To decide experimentally whether we have a root law or not, would require a grating constant of about 2 mils, and markings as fine as 0.2 mil or better. Even so, there are quite naturally enough other sources of error in this difficult experiment to justify doubt in its ability to decide the issue numerically. By comparison, the electrostatic analysis of the structure has a better claim to ultimate accuracy, besides giving the satisfaction of deriving gamma from first fundamentals, and for any set of structural parameters.

In the final phases of the NTSC, a special subcommittee was set up to study problems related to gamma. As a result of numerous measurements, now published in the unabridged minutes of the NTSC, an average gamma factor of 2.2 has been adopted as a standard for American color TV.

The overwhelming experimental evidence at this time seems to adequately support the thesis of the original paper.

Kurt Schlesinger
Head, TV Research Dept.
Motorola, Inc.
4501 W. Augusta Blvd.
Chicago, Ill.

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* Received by the IRE, July 13, 1954.

[1] Proc. I.R.E., vol. 41, pp. 528–532; April, 1953.

[2] "The Electron Gun Cathode Ray Tube, Part II," *Proc. British IRE*, vol. 6, pp. 99–129; May, 1946.

[3] Received by the IRE, August 16, 1954.

## Surface Loss of Silver Plated Metal Plates at 9,000 mc and Its Correlation with Surface Roughness*

Many researchers[1–3] have reported that waveguide attenuation and surface conductivity of metal plates and wires were greater than expected from the theory (due to their surface roughness), and the discrepancy was most remarkable in silver-plated samples.

Surface loss of the metal samples by the cavity method was measured, and simultaneously their surface condition by the mechanical stylus and electron micrograph methods, was measured, to investigate in more detail their correlation with each other. The mechanical stylus method was used to measure the microscopic surface roughness, while the electron micrograph was intended to investigate the microscopic detail of the surface condition.

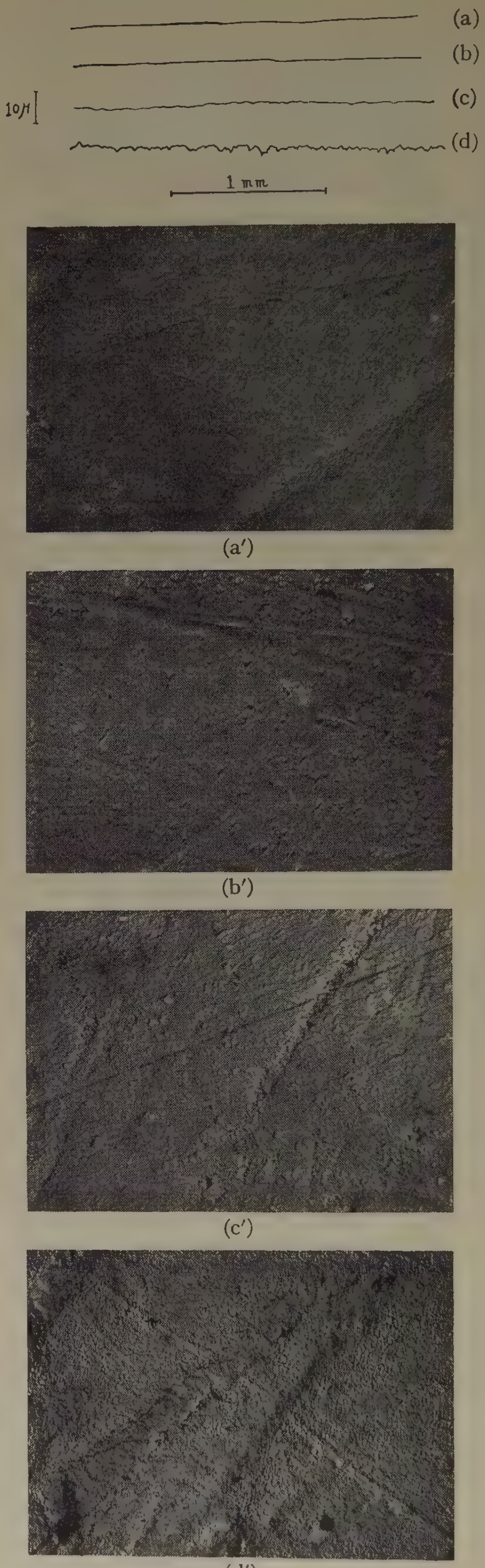
The relative surface loss of a metal plate can be measured from the variation of the $Q_s$ of the cylindrical cavity by fitting it at one end of the cavity. This is because the $Q$ of the cylindrical cavity varies according to the surface loss of its end plates. A $TE_{021}$ mode flat, cylindrical cavity, with a diameter of 12.5 cm and an axial length which was variable from 1.8–2.2 cm, was used in the 9,000 mc band in order to determine the loss of the end plates.

To avoid the influence of other spurious modes upon the value of $Q$, the cavity was provided with a choke noncontact flange at the contact point between the cylindrical wall of the cavity and the metal sample, and the wave absorber was inserted behind the variable end plate. The sample plates used were cylindrical discs of 14.0 diameter and maintained mechanical rigidity of 1.0 cm thickness. Suppose that two metal plates, of which the surface attenuation relative to pure copper is $A_1$ and $A_2$ respectively, are attached closely to one end of the cavity, and the values of the half-power bandwidth of the resonance curve are measured as $\Delta f_1$ and $\Delta f_2$ respectively. Then the following equation is obtained at 9,000 mc for the cavity described above:

$$\Delta f_2 - \Delta f_1 = 194\ (A_2 - A_1)\ \text{kc}.$$

Therefore, the unit difference, $A_2 - A_1 = 1.0$, corresponds to the frequency difference of 194 kc. Data was obtained directly from the oscilloscope trace; the measurement of the relative surface loss is accurate within 3 per cent.

The interesting results are illustrated in Fig. 1. The profilgraphs (vertical length is 1,000 magnification, horizontal length is 50 magnification) of the four samples in the direction parallel to the flow of the wall-current, and their electron micrographs (chromium-shadowed methylmetha-Al replica, 7,500 magnification) are presented. Sample (a) is a well finished pure copper and the ratio of its measured loss to the theoretical value is not more than 1.03, while sample (b), (c) and (d) are silver-plated brass, and their relative attenuations are 1.23, 1.50 and 2.05 respectively. The surface finishing of these samples is as follows: (a) lathe finishing and buffing; (b) lathe finishing, buffing, silver-plating several tens of microns thick and buffing; (c) lapping, thin silver-plating several microns thick and buffing; and (d) lathe finishing, paper polishing and silver-plating several microns thick.



(a′)

(b′)

(c′)

(d′)

Fig. 1—Profilgraphs (magnification 1,000×50) and electron micrographs (magnification 7,500); (a) (a′) copper plate (rel. loss 1.03), (b) (b′), (c) (c′) and (d) (d′) silver-plated samples (rel. loss 1.23, 1.50 and 2.05, respectively).

From the profilgraphs, electron micrographs and measured values of the surface loss, it can be seen that the surface loss increases rapidly with an increase in roughness of the surface. However, further inspection of the electron micrographs, indicates that there is considerable difference between the surface conditions of the pure copper sample and silver-plated sample; many silver particles irregularly deposited on the surface are visible in sample (b), the best one obtained in our laboratory. Moreover, not only the irregularly deposited silver particles, but also many abrupt seams and holes are visible on the surface of the usual silver-plated samples, (c) and (d).

The defective character of the silver-plated samples is considered the main cause of abnormal surface loss. This can be explained also from the experimental fact that the surface loss of the pure copper or brass plates varies in a systematic fashion with the roughness of their surfaces, as is known from the profilgraphs. The surface loss of the silver-plated samples does not always coincide with the microscopic roughness shown in their profilgraphs, but varies according to the microscopic appearance of the electron micrographs. Investigation is now being made on the relation between microscopic surface conditions, silver-plating, and finishing procedures.

Shigebumi Saito
Inst. of Industrial Science
University of Tokyo
Japan

[*] Received by the IRE, August 23, 1954.

[1] S. P. Morgan, Jr., "Effect of surface roughness on eddy current losses at microwave frequencies," *Jour. Appl. Phys.*, vol. 20, pp. 352–362; April, 1949.

[2] A. C. Beck and R. W. Dawson, "Conductivity measurements at microwave frequencies," Proc. I.R.E., vol. 38, pp. 1181–1189; October, 1950.

[3] F. A. Benson, "Waveguide attenuation and its correlation with surface roughness," *Proc. IEE, part III*, vol. 100, pp. 85–90; 1953.

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## On Isotropic Antennas*

A few years ago, I wrote a note[1] in which I concluded that an isotropic antenna is impossible. Although my conclusion was partially correct, my discussion may have been too brief to be easily understood. A few additional remarks appear to be in order.

A radiating antenna located at the origin of a spherical co-ordinate system was considered. In order for the conclusion to be correct, it must be possible to express the electric field intensity, at a great distance from the antenna, in the form

$$\begin{aligned} E = \frac{1}{r}\{&[f_1(\theta, \phi) \sin (\omega t - \beta r) \\ &+ f_2(\theta, \phi) \cos (\omega t - \beta r)]\boldsymbol{u}_\theta \\ &+ [f_3(\theta, \phi) \sin (\omega t - \beta r) \\ &+ f_4(\theta, \phi) \cos (\omega t - \beta r)]\boldsymbol{u}_\phi\}, \end{aligned}$$

where $\boldsymbol{u}_\theta$ and $\boldsymbol{u}_\phi$ are the unit vectors in the $\theta$ and $\phi$ directions, respectively. Many antennas do not satisfy this condition, e.g., antennas that move.

According to Brouwer's theorem,[2] there exist directions $(\theta_1, \phi_1)$ and $(\theta_2, \phi_2)$ such that $f_1(\theta_1, \phi_1) = f_3(\theta_1, \phi_1 = 0$ and $f_2(\theta_2, \phi_2) = f_4(\theta_2, \phi_2) = 0$. If $(\theta_1, \phi_1) = (\theta_2, \phi_2)$, there is no radiation in the $(\theta_1, \phi_1)$ direction. If $(\theta_1, \phi_1) \neq (\theta_2, \phi_2)$, the radiation in these directions must be linearly polarized.

H. F. Mathis
206 Linden Road
Kent, Ohio

[*] Received by the IRE, November 8, 1954.

[1] H. F. Mathis, "A short proof that an isotropic antenna is impossible," Proc. I.R.E., vol. 39, p. 970; August, 1951.

[2] L. E. J. Brouwer, "On continuous vector distributions on surfaces," *Proc., Royal Acad. (Amsterdam)*, English edition, vol. 11, pp. 850–858; 1909. Or, "Over continue vectordistributies op oppervlakken," *Proc., Koninklijke Akademie van Wetenschappen (Amsterdam)*, Dutch edition, vol. 11, pp. 896–904; 1909.

## Detection of Discrete Radio Sources at 21 cm Wavelength*

Receiving equipment at a wavelength of 21 cm has recently been installed in the fifty-foot radio telescope at the Naval Research Laboratory. The intent was to make a study of the 21 cm radiation from neutral hydrogen clouds in the galaxy. The receiver was so designed that it was possible to observe not only the hydrogen radiation but also the background continuum at a frequency displaced about 3 mc from the hydrogen line frequency. Simultaneous measurements of hydrogen line radiation at the position of and adjacent to certain sources indicated a sizable reduction of the hydrogen radiation at the position of the source, indicating that the source itself was absorbing the 21 cm hydrogen radiation coming from regions beyond. The material on galactic absorption is being presented elsewhere in detail.[1] Twenty discrete sources of radio noise were located and measurements of antenna temperature, flux, and position were made.

The receiver uses two channels, one approximately 1.9 mc wide normally used as a comparison channel in hydrogen measurements, and a second channel of adjustable bandwidth (5 kc to 55 kc) tuned to the hydrogen radiation, whose frequency in the absence of doppler shift is 1420.405 mc. These two channels are separated by 3.25 mc. The continuum measurements were made by recording the output level of the wide comparison band alone on a chart recorder while a second recorder recorded the difference between the comparison band and the narrow hydrogen signal band. The receiver employs a crystal mixer mounted in a waveguide, and the noise figure in both channels is 9.7 db as measured by means of a fluorescent tube noise source.

The antenna beamwidth was measured as 55 minutes of arc in the *H* plane using the radio source in Cassiopeia as an assumed point source. An absolute gain measurement of the antenna has not as yet been made but since the calculated beamwidth is almost exactly 55 minutes and the side lobes have been measured to be more than 20 db below the main lobe, it is felt that it is safe to quote an illumination efficiency of 0.65. The noise figure measurements are thought to be accurate to ±0.5 db or ±12 per cent at the time they were made. The possibility of the noise figure changing during a run, plus a possible over-estimate of antenna efficiency, would lead us to believe that the temperatures and fluxes quoted have a probable error of +20 per cent to −15 per cent. The antenna was bore sighted on a source set up in the Washington Monument at a distance of 4½ miles and adjusted to indicate the correct hour angle and declination of that point. The uncertainties involved in determining a source position with a 55-minute beam, plus uncertainties due to the antenna control system, lead us to believe that the probable error in the quoted positions is ±15 minutes of arc, depending on the strength of the source.

Table I is a list of the sources located, with the measured antenna temperature, the position, and the calculated value of flux for the sources of small angular extent. The flux is quoted in units of watts/square meter/cycle bandwidth/seconds, and contains a factor of two to account for that plane of polarization which is not accepted by the antenna.

The table lists the 21 cm sources in the order in which they were observed at this wavelength. Fourteen of these sources had not been observed before at 21 cm, and seven of the sources are reported here for the first time. Of the seven, four have been seen at 9.4 cm, two (15 and 16) prior to their observation at 21 cm, and two (12 and 14) subsequent to that time. The remainder include all but one (M8) of the sources seen by Haddock, Mayer, and Sloanaker at 9.4 cm wavelength,[4] IC443, Cygnus X, and Aquila. The identified extragalactic sources include (3) Cygnus A, the well-known pair of colliding galaxies, (7) Centaurus, identified as NGC-5128, another instance of galaxies in collision, and (8) Virgo, M87, the peculiar galaxy with the "jet" extending from the nucleus. The galactic sources include two groups: ten *H* II regions, seen only at 9.4 and 21 cm wavelength, and the high velocity emission nebulae, (1) Cassiopeia and (2) Taurus, observed extensively at other wavelengths, and (13) IC443, observed at 3.7 and 7.9 meters[7] and recently at 9.4 cm.

In the case of the *H* II regions the optical position of the object was used as a guide in searching for radiation at 21 cm. The position determined for each of these sources agreed with the optical position well within the limits of accuracy. The five new sources are (12) NGC6604, (19) S45, (17) S79 (through which Haddock, Mayer, and Sloanaker had previously made a right ascension sweep), (14) M16, and (18) Orion B, a weak source centered near the Horsehead Nebula. In addition four sources which are unidentified with visual objects were observed. Cygnus X (11), the extended source observed by Piddington and Minnett,[5] and a source in Aquila (20), identified by Mills as (19+07) were found. The remaining two have been discussed as NRL No. 5 and No. 9.[1] They represent the complex source noted above, which consists of source No. 5 superposed on the much wider No. 9. It is this pair of sources which exhibits the strongest case of hydrogen absorption yet found.

TABLE I
Sources Observed at 21 cm Wavelength

| No. | Source | R.A. | Dec. | $T_a$°$K$ | Flux $\times 10^{-25}$ $w/m^2/c/s$ | Remarks |
|---|---|---|---|---|---|---|
| 1 | Cassiopeia | $23^h\ 21^m$ | +58° 32′ | 115 | 266 | High velocity emission nebula[2] |
| 2 | Taurus | 5 31 | +22 30 | 46 | 106 | Crab Nebula, remnant of supernova[3] |
| 3 | Cygnus A | 19 58 | +40 30 | 63 | 146 | Colliding galaxies[2] |
| 4 | M17 | 18 17 | −16 00 | 35 | 82 | Omega Nebula, H II Region[4] |
| 5 | NRL No. 5 | 17 43 | −28 45 | 73 | 170 | Complex source[4] with No. 9 showing *H* I absorption[1] |
| 6 | Orion | 5 32 | − 5 20 | 18 | 42 | M42, The Orion Nebula, *H* II Region[4] |
| 7 | Centaurus | 13 22 | −42 40 | 17 | 40 | Colliding galaxies, NGC5128[8] |
| 8 | Virgo | 12 27 | +12 20 | 13 | 30 | Galaxy with "jet" M87[8] |
| 9 | NRL No. 9 | 17 43 | −28 45 | 6 |  | Extended source near No. 5[4] |
| 10 | M20 | 17 57 | −23 03 | 18 | 42 | Trifid Nebula, *H* II Region[4] |
| 11 | Cygnus X | 20 40 | +40 40 | 16 |  | Extended source of Piddington and Minnett[5] |
| 12* | NGC6604 | 18 16 | −12 10 | 4 | 9 | Emission Nebula, *H* II Region[6] |
| 13 | IC443 | 6 13 | +22 40 | 7 | 16 | High velocity emission nebula[7] |
| 14* | M16 | 18 17 | −13 40 | 9 | 21 | NGC 6611, *H* II Region |
| 15 | S78 | 20 22 | +40 20 | 15 | 34 | Emission Nebula, *H* II Region[6] |
| 16 | NGC7000 | 20 53 | +44 30 | 4 |  | North America Nebula, *H* II Region[8] |
| 17* | S79 | 20 30 | +43 45 | 3 | 7 | Emission Nebula, *H* II Region[6] |
| 18* | Orion B | 5 39 | − 1 30 | 2 | 5 | Near Horsehead Nebula, *H* II Region |
| 19* | S45 | 18 24 | −12 20 | 11 | 26 | Emission Nebula *H* II Region[6] |
| 20 | Aquila | 18 59 | + 5 | 4 | 9 | Mills (19+07)[9] |

* First radio observation of this source.

A more detailed description of this work including a discussion of the spectra of the sources will be published later.

J. P. Hagen, E. F. McClain,
and N. Hepburn
Naval Research Lab.
Washington, D. C.

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* Received by the IRE, June 7, 1954.

[1] J. P. Hagen and E. F. McClain, "Galactic absorption of radio waves," *Ap. J.*, vol. 120 (in press).

[2] W. Baade and R. Minkowski, "Identification of the radio sources in Cassiopeia, Cygnus A, and Puppis A," *Ap. J.*, vol. 119, p. 206; 1954.

[3] J. G. Bolton, G. J. Stanley, and O. B. Slee, "Positions of three discrete sources of galactic radio-frequency radiation," *Nature*, vol. 164, p. 101; 1949.

[4] F. T. Haddock, C. H. Mayer, and R. M. Sloanaker, "Radio emission from the Orion nebula and other sources at λ 9.4 cm," *Ap. J.*, vol. 119, p. 456; 1954.

[5] J. H. Piddington and H. C. Minnett, "Radio-frequency radiation from the constellation of Cygnus," *Aust. Jour. Sci. Res.*, A, vol. 5, p. 17; 1952.

[6] S. Sharpless, "A catalogue of emission nebulae near the galactic plane," *Ap. J.*, vol. 118, p. 362; 1953.

[7] J. E. Baldwin and D. W. Dewhirst, "Position and identification of a bright extended radio source in Gemini," *Nature*, vol. 173, p. 164; 1954.

[8] F. T. Haddock, C. H. Mayer, and R. M. Sloanaker, "Radio observations of ionized hydrogen nebulae and other discrete sources at a wavelength of 9.4 cm," *Nature*, vol. 174, p. 176; 1954.

[9] B. Y. Mills, "The distribution of the discrete sources of cosmic radio radiation," *Aust. Jour. Sci. Res.*, A, vol. 5, p. 266; 1952.

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## Comment on "Ages of Creativeness of Electronic Engineers"*

**Russell Coile**[1]

Studies of this kind are of value in appraising human behavior and enhancing the efficiency of mass effort. Reading this particular article does raise some questions concerning the foundations on which the study was based because of the effect on the conclusions and their applications.

In a way one must try to consider what is creativeness and in what degree. Certainly the opportunity to do creative work has a large influence on what is created. Relatively few creative acts are the result of isolated inspirations. In electronics especially, the man usually is member of a team of workers engaged in the business of solving problems of all magnitudes. Some problems come from pressure of circumstances imposed by previously existing conditions. Others are consciously selected problems, the solution of which may yield results believed to be desirable. We call this a new field.

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* Received by the IRE, August 23, 1954.

[1] Proc. I.R.E., vol. 42, p. 1322; August, 1954.

The way things often occur in organized technical and scientific effort is something like this: Senior personnel of broad experience conceive a field of inquiry that is either required, or judged to be attractive. Facilities and manpower are assembled and assigned to the task. The wisdom and judgment involved in selecting and providing for the technical assault is certainly of as high creative merit as the later acts of creation resulting from the opportunity and challenge assigned to each worker. Is not the financing and building of a well-equipped laboratory or shop, and the selection of the staff, as creative as the subsequent creative acts within it? However, it is from the latter that our technical literature is expanded. The author of the paper that is published is not always the one to whom credit for creation should go. On strictly technical grounds, the act of creation may have been by a much older man in supervisory or executive station who framed the problem and probably provided much of the counsel and advice that brought a successful result. There are times when a wise senior engineer literally squeezes creativity from one of his staff by encouragement, personality guidance, and training in thought processes. Co-workers also have the same general influence on each other. Virtually always a new idea is greatly expanded and improved by consultations with supervision and members of the team. In this complex it is often hard to say to whom the credit for creation should go. Creativity is a way of thinking that most young men have to be taught by their elders.

Is the man, or group, who writes a specification for a development project, or an apparatus, any less creative than the man who invents something important in his effort to meet the specification? For without the problem, the solution may never have been invented.

Without detracting in the least from the credit due to the younger men in the electronic field, as indicated in Mr. Coile's article, I feel that the method he used to measure individual creative credits has to be questioned in a field like electronics, where team effort is the rule. Certainly a very large share of the active work is done by younger men who are encouraged, and even pushed, into writing the results of their work for publication by the older men. Naturally there are more men in the ranks than in supervisory and executive functions; yet we know that wars have always been won more on generals' strategy than on individual acts of heroism that always make the best news. Degree and value of a creative act has to be considered in any broad appraisal of this sort.

Thinking back over some thirty years of association with hundreds of engineers of all ages in electronics, my belief is that some of the most important creative acts come from the ages 45 and above; also that the incidence of important new ideas and new fields is higher in that age group than the ages represented by authors of the bulk of technical papers. It must also be recalled that many really great engineers and "idea men" have never published any papers. Also, when you know certain men and what they have done creatively over a lifetime, their technical papers at best give only a slight indication of their creativity.

The data presented by Mr. Coile should, in my opinion, lead to this kind of a conclusion: During the period of an engineer's life when he is mostly working with "things," his creativity peaks between 30–34 years. For those who work with men, ideas, and facilities, the years of best creativity are usually beyond 40.

Mr. Coile is to be congratulated on having contributed his study, and my discussion is only to suggest that the data should be "weighted," in order not to be led astray, when it comes to appraising and assigning our manpower.

EDMUND A. LAPORT
Chief Engineer
RCA International Div.
30 Rockefeller Plaza
New York 20, N. Y.

## The Resistivity of "Composition" Resistors at Radio Frequencies*

The lowering of resistance, which occurs in "composition" (carbon-resin) resistors upon the increase of frequency (Boella effect[1]), has been explained by Howe[2] on the basis of external distributed capacitances. In the theory of this author, the resistivity of the carbon-resin mixtures is assumed to be independent of frequency. In a recent publication,[3] we have pointed out that this hypothesis cannot be accepted *a priori*. If we suppose that the resistivity depends on frequency, and denote it by the symbol $\bar{\rho}_f$, the formula by Howe must be written:

$$\bar{Z} = \bar{\rho}_f \frac{l}{S} \bar{H} \tag{1}$$

where $\bar{Z}$ is the impedance measured between the terminals of resistor, $l$ and $S$ indicate the length and the section respectively, and $\bar{H}$ is the complex factor calculated by Howe, which will be called here "external capacitance factor" (e.c. factor):

$$\bar{H} = \frac{\tanh\left(l\sqrt{\omega C_1 R_1}\, e^{j(\pi/8)}\right)}{l\sqrt{\omega C_1 R_1}\, e^{j(\pi/8)}} \tag{2}$$

where $C_1$, $R_1$ = external capacitance and dc resistance in the unitary length.

In this note we shall give a preliminary account of experimental research made for the purpose of determining the relative amounts of the influence of e.c. factor and of "resistivity factor," $\bar{\rho}_f\, l/S$, upon the lowering of the real part of $\bar{Z}$ as $f$ increases.

The individual values of "resistivity" and of "e.c." factors at high frequencies may be determined by various experimental procedures. In our research we have selected for the criterion of study a resistor made of a material whose resistivity has a dependence upon frequency, which is *a priori* well known. The electrolytic solutions represent a material well suited to this purpose, since the behavior of its resistivity with increase of frequency has been completely studied both experimentally and theoretically (Debye, Falkenhagen, Onsager, Wilson, Sandwed, La Mer, and others[4]), so that we know the calculation, with neglectable errors, of the lowering of resistivity with the increase of frequency (Debye-Falkenhagen effect). According to the theory of electrolytes, it may be pointed out that this lowering is determined by the interionic electrostatic forces; the effect then vanishes when these forces $F_{ij}$ tend to disappear. The average of $F_{ij}$ is of the type:

$$F_{ij} = \frac{q_i q_j}{4\pi\epsilon\epsilon_0 r_{ij}^2} \tag{3}$$

where $q_i$, $q_j$ are the charges of a pair of ions; $\epsilon$ = relative dielectric constant of the solvent; $\epsilon_0$ = absolute dielectric constant of the vide; $r_{ij}$ = average interionic distance. In a greatly diluted watery solution, owing the high value of $\epsilon(=81)$ and of $r_{ij}$, $F_{ij}$ is of too small a magnitude to determine a valuable correlation in thermal movements. For a watery solution of sodium chloride, having a concentration of 0.6 mg/liter, the lowering of $\rho_f$ is practically neglectable up to 100 mc. The lowering of the resistance of a resistor, which has been made by means of a solution of that type, if we observe any, therefore, must be ascribed to e.c. factor exclusively.

For the experimental part of the present study we have employed two Rohde-Schwartz apparatus. The "Leitwertsmesser V.L.U." from 0.1 to 10 mc, and the "Leitwertsmesser V.L.U.K." from 10 to 100 mc. Since for 100 $K\Omega$ these instruments give the best approximation, we have chosen a group of resistors having this order of resistance for our measurements. Three of these resistors are as follows: (a) cylindrical column of watery solution of sodium chloride 0.6 mg/liter (molarity $10^{-5}$), $l=30$ mmq, $S=78.6$ mmq, $\rho_f=262$ Ωm (practically independent by frequency up to 100 mc), resistance = 100 $K\Omega$, contained in a plexiglas tube, (b) cylindrical column of a watery solution of copper sulphate, concentration 0.8 $g$/liter (molarity $5.10^{-8}$), $\rho_f=2.84$ Ωm at 1 kc (showing marked Debye-Falkenhagen effect, according to theory of electrolytes), $l=50$ mm., $S=0.786$ mmq, resistance at 1 kc 180 $K\Omega$, (c) cylindrical column of carbon-resin solid mixture of commercial U. S. type, $l=30$ mm, $S=38.5$ mmq, $\rho_f=128.3$ Ωm at 1 kc, $\epsilon$ of resin = 2 (approximately), resistance at 1 kc = 100 $K\Omega$.

The results obtained are given in Figs. 1, 2, and 3 on the following page. The resistance of resistor (a) is practically independent of frequency up to 100 mc: the e.c. factor, therefore, is = 1 in that band. Since the external capacitances of the liquid column, having a diameter of 10 mm, are noticeably greater than in commercial resistors of normal types, we must deduce that the e.c. factor is to be assumed = 1 up to 100 mc in ordinary technical applications, provided the surrounding conducting walls are far off from the surface of resistor.

The resistance of resistor (b) shows a very marked lowering, which is ascribed to

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* Received by the IRE, July 30, 1954.

[1] M. Boella, "Prove su isolatori per linee ad onde quidate," *Alta Frequenza*, vol. I, p. 221, 1932; "Sul comportments alle alte frequenze di alcuni tipi di resistenze elevate in uso pei radio circuiti," vol. III, p. 132, 1934.

[2] G. W. O. Howe, "A further note on high resistances at high frequencies," *Wireless Eng.*, vol. XII, p. 413; 1935.

[3] U. Tiberio, "Sulla tesria del l'effetts Boella," *Alta Frequenza*, vol. XXII, p. 184; 1953.

[4] See, for example, H. S. Harned and B. B. Owen, "The Physical Chemistry of Electrolytic Solutions," Reinhold Publ. Corp., New York, N. Y.; 1943.

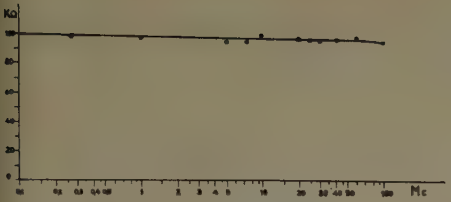

Fig. 1—The resistance of a resistor of the *a*-type in dependence upon frequency up to 100 mc.

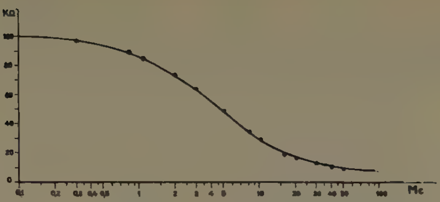

Fig. 2—The resistance of a resistor of the *b*-type in dependence upon frequency up to 100 mc. Values of the resistance are proportionally referred to 100 KΩ dc value.

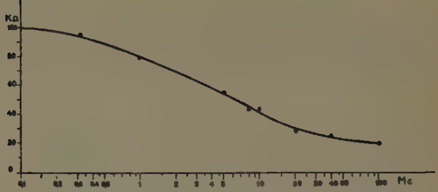

Fig. 3—The resistance of a resistor of the *c*-type in dependence upon frequency up to 100 mc.

the Debye-Falkenhagen effect exclusively, as the calculations on the basis of formulas of electrolytic theory prove. The e.c. factor can be assumed =1, since the external capacitances are inferior to that in resistor (a).

In resistor (c), we have a marked lowering too, which we cannot ascribe to e.c. factor, since the external capacities are likewise inferior in respect to that in the case of (a). We must, therefore, conclude that the lowering, which we note in the (c) resistor, is a "resistivity" effect.

In the Debye-Hückel theory, the resistivity of electrolytic solutions analogously decreases with an increase of the dc electric field (Wien effect). The analogy which has been established between electrolytic solutions and carbon-resin mixtures in the preceding paragraph lead us to examine whether or not this analogy extends itself to the Wien effect.

A group of accurate measurements, about which we are not referring here, has proved that the said analogy is extended to dc behavior too. Since the Wien effect cannot be explained by means of a theory of the type presented by Howe, we have a further reason to believe that the lowering of resistance with an increase of both frequency and of the dc field, must be explained on the basis of a theory of the "resistivity" type.

A further group of measurements has been carried out on the influence of a cylindrical metallic wall surrounding the resistor. The increase of the external capacitances so produced yields a lowering of resistance, which can be ascribed exclusively to e.c. factor, according to theory by Howe. Thus it has been confirmed that the external capacitances of a resistor, when all metallic walls are far away, are too small for the e.c. factor to vary appreciably from unity.

In connection with these measurements we have considered building a group of resistors made by a solid mixture of carbon with a material having a very high dielectric constant, and then submitting them to an analogous experimental study. We may then find a curve like that in Fig. 1. The results of this study will be published later.

In conclusion, the lowering of resistance of composition resistors, which occurs with an increase of frequency, is ascribed partly to "resistivity factor" and partly to "e.c. factor." In the band up to 100 mc the e.c. factor is assumed almost =1 for resistors of up to some hundreds of $K\Omega$. Resistors, whose resistances are independent of frequency up to 100 mc, may be built by employing very diluted watery solutions. A solid material, with similar characteristics, as far as the independence of frequency is concerned, may presumably be obtained by mixing carbon with a dielectric material having high dielectric constant.

Ugo Tiberio
Prof. of Radio Engineering
University of Pisa
Italy

# Contributors

H.P. Birmingham

H. P. Birmingham (M'53) was born in Newburgh, N. Y., on March 17, 1920. He received the Bachelor of Education degree in 1942 from the Rhode Island College of Education, and has since done graduate work in psychology at the University of Pennsylvania, and at the American University.

He served in the Air Force as an instructor in radar maintenance and as a classification specialist. He later joined the research staff of Brown University as research psychophysiologist under NDRC and received the Navy Bureau of Ordnance Development award for work in fire control. He joined the Psychology Branch of Radio Division III, Naval Research Laboratory, in 1945. This work includes human engineering of all types of Navy equipment.

Mr. Birmingham is a member of the American Psychological Association and the Eastern Psychological Association.

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J. J. Ebers

J. J. Ebers (S'46–A'48) was born in Grand Rapids, Mich., on November 25, 1921. He received the B.S. degree from Antioch College in 1946, his education having been interrupted by three years' service in the U. S. Army. He obtained the M.S. degree in electrical engineering from Ohio State University in 1947, and the Ph.D. in 1950.

From 1947 to 1951 Dr. Ebers was an instructor and later an assistant professor in the electrical engineering department of Ohio State University, as well as research associate for the Ohio State University Research Foundation. In September of the latter year he joined the transistor development group of Bell Telephone Laboratories at Murray Hill, N. J.

Dr. Ebers is a member of Eta Kappa Nu, Sigma Xi, and APS.

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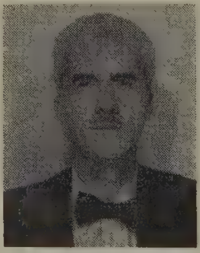

W. R. MacLean

W. R. MacLean (A'42) was born on July 14, 1908, in Marinette, Wis. He was in amateur radio from 1921 until graduating from M.I.T. in 1929. During the following year he worked on early problems in oscillography in the Bell Telephone Laboratories, and in 1930–31 he studied physics at Munich, Berlin, and the Sorbonne. He did actuarial and statistical work from 1932–37, when he began working on acoustical measurements and sonar prob-

# Contributors

lems for the Navy and Signal Corps. He joined the Polytechnic Institute of Brooklyn in 1941, and subsequently received the D.E.E. degree for work in microwaves. He is now serving there as Professor of Electrical Engineering and directs the department's Graduate Thesis Laboratory, administering its thesis research program.

Dr. MacLean has also been active in the fields of electronic statistics, general gadgetry, modern physics, and electromagnetic theory. He is a licensed P.E. of New York State and has been a consultant for various firms.

He has been a member of the Acoustical Society and the American Physical Society, and he is a member of Tau Beta Pi and Sigma Xi.

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D. A. McLean

D. A. McLean was born in Golden, Colo., on July 15, 1905. Since graduation from the University of Colorado in 1929 with the degree of B.S. in chemical engineering, he has been a member of the technical staff of Bell Telephone Laboratories. He has been primarily concerned with the chemical aspects of electrical insulation with particular reference to capacitor dielectrics. In this field he has a number of patents and other publications. Recently, his work has emphasized miniaturization of capacitors, resistors and other passive components.

Mr. McLean is a member of the American Chemical Society, Sigma Xi, and Tau Beta Pi. He is chairman of the Conference on Electrical Insulation of the National Research Council.

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J. L. Moll

J. L. Moll (A'51) was born on December 21, 1921, in Wauseon, Ohio. He received the B.Sc. degree in engineering physics in December, 1943 from the Ohio State University, and the Ph.D. degree in electrical engineering in 1952.

Mr. Moll worked at the Radio Corporation of America during the years 1944 and 1945. From 1945 to 1948 he was employed as a graduate assistant in the mathematics department at Ohio State University, and from 1948 to 1952 was an instructor in the electrical engineering department, as well as a research associate for the Ohio State University Research Foundation. Since September, 1952 Mr. Moll has been a member of the Bell Telephone Laboratories' staff, where he has been working on transistor development.

Mr. Moll is a member of Sigma Xi.

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For a photograph and biography of J. R. Pierce, see page 512 of the March, 1954 issue of the Proceedings of the I.R.E.

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G. E. Pihl

G. E. Pihl (A'41) was born on February 22, 1915, at Brockton, Mass. He received the B.S. degree in electrical engineering from Northeastern University in 1937, and the M.S. degree in communications engineering from the Harvard Graduate School of Engineering in 1939. In 1938 he became a member of the faculty of Northeastern University, and taught in the electrical engineering department until 1953. At that time he left his position as associate professor to join the engineering staff of the Technology Instrument Corporation, Acton, Mass.

He is a member of the AIEE, Eta Kappa Nu, and Tau Beta Pi.

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F. V. Taylor

F. V. Taylor was born in Proctor, Vt., on December 13, 1910. He received the Ph.B. degree from Brown University in 1932 and the M.A. and Ph.D. degrees in psychology at Princeton, receiving the latter degree in 1935. From 1935 to 1936 he worked at Yale University as a Research Assistant. From 1936–1944 he taught psychology at Princeton University. He joined National Defense Research Council Project N-111 in 1944 to work on "psychological problems relating to the use of lead-computing gun sights and the directors to which the gun sights are attached." He received the Navy Bureau of Ordnance Development award for work on the project.

He joined the Naval Research Laboratory in 1945 to start a human engineering group to work on gun fire control problems. The mission of the group gradually expanded to include human engineering of all types of Navy equipment. He is at the present time the Head of the Engineering Psychology Branch, Applications Research Division, Naval Research Laboratory.

Dr. Taylor is a member of RESA, the American Psychological Association, the American Association for Advancement of Science—Diplomate in Industrial Psychology, and the American Board of Examiners in Professional Psychology.

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U. Tiberio

Ugo Tiberio was born in Campobasso, Italy, on August 19, 1904. He received the Sc.M. degree in engineering from Naples University in 1927.

From 1927 to 1936 Mr. Tiberio was a research associate at the Institute of Electrical Communications of the Italian Army in Rome, concerned with ultra-short wave research and, after 1934, military and cw radar. He then joined the Institute of Electrical Communications of the Italian Navy at Leghorn, where he went on to research on pulse radar, making many valuable contributions to the design and construction of radar for the Italian Army and Navy. In 1941 he became professor of electrical engineering at the Italian Naval Academy.

At present Mr. Tiberio is professor of radio engineering at the University of Pisa, where he also engages in research.

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H. G. Wehe

H. G. Wehe was born on April 8, 1900, in Topeka, Kan. He received the A.B. degree from Washburn College in 1922, and the M.A. degree from the University of Kansas in 1925. He taught physics and chemistry and spent one summer in test-board work with the Southwestern Bell Telephone Company. In 1926 he joined the E. of M. Department of Western Electric, transferring in 1929 to Bell Telephone Laboratories as a member of the research department technical staff.

His first work was in magnetics and on the deposition of carbon films on ceramic materials. Since 1933, except for a year developing radar tubes during World War II, he has been engaged in studies of vapor deposition of thin films either of the semi-transparent or nonreflecting types, or to serve as electrodes or resistors.

Mr. Wehe holds a number of patents in the fields of electrochemistry, ceramics, and pyro-magnets, and invented the pyro-magnetic solar motor.

# IRE News and Radio Notes

## Calendar of COMING EVENTS

**IRE-AIEE-ACM Eastern Computer Conference, Bellevue-Stratford Hotel, Philadelphia, Pa., December 8–10**

**IRE New York Section Symposium on Design Principles of Transistor Circuits, Engineering Societies' Building, New York, N. Y., January 8**

**IRE-AIEE-NBS-URSI Conference on High Frequency Measurements, Hotel Statler, Washington, D. C., January 17–19**

RETMA Symposium on Printed Circuits, University of Pennsylvania, Philadelphia, Pa., January 20–21

IAS Twenty-Third Annual Meeting, Hotel Astor, New York City, January 24–28

**IRE-IAS-ION Electronics in Aviation during IAS Convention, Astor Hotel, New York City, January 26**

**IRE-AIEE Conference on Transistor Circuits, Philadelphia, Pa., February 17–18**

**IRE-AIEE-ACM Western Computer Conference, Hotel Statler, Los Angeles, Calif., March 1–3**

**IRE National Convention, Waldorf-Astoria Hotel and Kingsbridge Armory, New York, N.Y., March 21–24**

**IRE-PIB Symposium on Modern Network Synthesis, Engineering Societies Building, New York City, April 12–15**

**IRE Seventh Region Technical Conference, Hotel Westward Ho, Phoenix, Ariz., April 27–29**

**National Aeronautical Electronics Conference, Biltmore Hotel, Dayton, Ohio, May 9–11**

**IRE-AIEE-IAS-ISA National Telemetering Conference, Hotel Morrison, Chicago, Ill., May 18–20**

**IRE-AIEE-RETMA-WCEMA Electronics Components Conference, Los Angeles, Calif., May 26–27**

URSI-U. of Michigan International Symposium on Electromagnetic Wave Theory, University of Michigan, Ann Arbor, Mich., June 20–25

### A. N. GOLDSMITH HONORED BY NATIONAL TV FILM COUNCIL

Dr. Alfred N. Goldsmith, Editor Emeritus and co-founder of the IRE, was honored recently at a testimonial luncheon sponsored by the National Television Film Council at the Warwick Hotel, New York City. Over 200 representatives of the television industry were on hand to see Dr. Goldsmith receive a scroll and brief case from the NTFC.

A. V. Loughren, director of research at the Hazeltine Corporation, gave the luncheon address in which he cited Dr. Goldsmith's contributions to radio, phonograph, film, and television fields. The toastmaster was Cliff Norton who substituted for Milton Berle, unable to attend because of illness.

Among his many activities Dr. Goldsmith is consultant to RCA, NBC, Eastman Kodak, and RKO Theatres, Chairman of the Board of the TTFC, and a member of the IRE Board of Directors.

### IRE-AIEE CONFERENCE ON TRANSISTOR CIRCUITS TO BE HELD IN PHILADELPHIA

The Professional Group on Circuit Theory, the Science and Electronics Division of the AIEE, and the University of Pennsylvania will sponsor jointly a Conference on Transistor Circuits, February 17–18, 1955 at the University of Pennsylvania in Philadelphia.

Rapid strides have been made in the transistor art since the last circuits conference in Philadelphia earlier this year, and the 1955 conference will try to cover this broad advance. Papers dealing with current trends in linear and pulse circuit techniques will be included. As in the past, the conference will be designed primarily for engineers working actively with transistor circuits.

### ENGINEERS HONORED AT AUDIO BANQUET

Outstanding figures in audio were honored at the annual banquet of the Audio Engineering Society, held in the Hotel New Yorker, New York. The John H. Potts Award for outstanding achievement in audio engineering was given to Joseph P. Maxfield of Espanola, New Mexico, for his improvements in studio, theater, industrial and military acoustics. The society's award for service went to John D. Colvin, Gates Radio Company.

Dr. Frederick V. Hunt, Harvard University, received the Emile Berliner Award in recognition of his analysis of tracing distortion in disc reproduction, his work on underwater sound systems, and his studies in acoustical measurement techniques. The society gave an honorary membership to Harold S. Black, Bell Telephone Laboratories, for his work in development of stabilized feedback amplifiers. A citation was awarded posthumously to Harold T. Sherman for work in the advancement of binaural sound.

Seventeen fellowships were awarded for outstanding work in the audio engineering field. The recipients included: Benjamin B. Bauer, Leo L. Beranek, Harry L. Bryant, Robert Dresser, Cyril M. Harris, Richard F. Hastings, Edward W. Kellogg, Hugh S. Knowles, Harold J. Leak, Walter E. Lehnert, Vincent J. Liebler, Theodore Lindenberg, Charles McProud, William H. Offenhauser, Vincent Salmon, Ralph A. Schlegel, and W. Oliver Summerlin.

### MATHEMATICS SOCIETY HOLDS FIRST NATIONAL MEETING

The Society for Industrial and Applied Mathematics will hold its first national meeting in conjunction with the annual meetings of the American Mathematical Society, the Mathematical Association of America, and the Association for Symbolic Logic at the University of Pittsburgh, December 27–29. The following addresses will be presented to an evening meeting: "The History of a Problem," Dr. Brockway McMillan, Bell Telephone Laboratories; "The Control of Industrial Operations," Prof. Herbert A. Simon, Carnegie Institute of Technology; "Probability Theory in Liability and Property Insurance," Mr. C. W. Crouse, Preslan and Company. Further information may be obtained from Mr. H. W. Kuhn, Dalton Hall, Bryn Mawr College, Bryn Mawr, Pennsylvania.

### R. D. KELL RECEIVES DAVID SARNOFF GOLD MEDAL

The Society of Motion Picture and Television Engineers announced Ray D. Kell recipient of the 1954 David Sarnoff Gold Medal Award for his pioneering achievements in all-electronic television and for his contributions to color television. He has to his credit more than 36 inventions in the field of television and communication.

Mr. Kell, a member of the television research staff of the RCA Laboratories Division, was presented the award at a luncheon opening the society's 76th semiannual convention in Los Angeles. The David Sarnoff Gold Medal Award was established for technical contributions to television and is awarded primarily for achievements within the last five years.

### SYMPOSIUM ON PRINTED CIRCUITS TO BE HELD IN JANUARY

RETMA will hold a Symposium on Printed Circuits, January 20–21, 1955 in the University of Pennsylvania auditorium in Philadelphia. The symposium will promote understanding of the practical techniques, problems and applications of Printed Circuits, and provide an opportunity for discussion of the more recent accomplishments in this field.

The tentative agenda for the program is: Product Design Applications, Reliability and Serviceability, Management Considerations, Panel Session on Techniques of Producing Printed Wiring Boards, Printed

Components and Components for Use With Printed Wiring, and Production Techniques and Manufacturing Methods.

An effort will be made to obtain papers dealing with the practical phases of Printed Circuits and containing specific data rather than theoretical papers. The papers presented at the symposium will be published in an official *Proceedings* which will be made available to the public. Acknowledgements will be sent to those submitting abstracts, as soon as possible after receipt, by the Technical Program committee.

## First Eastern Hemisphere Section Formed in Israel

The establishment of the first IRE Section in the Eastern Hemisphere, the Israel Section, was approved by the IRE Board of Directors at its October meeting. Formation of this Section, generated spontaneously by members there, reflects the growing international scope of IRE activities. Of the seventy-four IRE Sections, there are ten outside the continental United States. These now include Israel, Buenos Aires, Hawaii, and seven in Canada.

The IRE welcomes this new Section whose establishment will be of particular interest to IRE members in other countries of the Eastern Hemisphere.

## OBITUARY

**Walter Albert Rush** (F'36–L'49), former Vice-President of the IRE, who retired nine years ago as Controller of Radio for the Department of Transport, died recently in Ottawa.

Mr. Rush joined the old Marconi Wireless Telegraph Company of Canada in 1905. He went to the Canadian government in 1912 as Chief Inspector of Wireless Service in the Department of Naval Services. When the Department of Transport was created in 1936, the government radio service was transferred to it, and Mr. Rush became Controller of Radio in the air-services branch.

W. A. Rush

During the war, he directed the facilities for intercepting short-wave radio transmissions from German surface and undersea raiders. He was responsible for the construction and development of facilities which provided radio aids to navigation for Canada's expanded air force, for the assignment of frequencies in the radio spectrum required by the armed forces, and for co-ordination of research to eliminate radio interference in service aircraft, ships, and vehicles. In addition, Mr. Rush served as liaison officer to co-ordinate frequency allocations with the United States, United Kingdom, and Newfoundland authorities.

He was a member of the Engineering Institute of Canada, the Professional Engineers of Ontario and the Professional Institute of the Civil Service of Canada.

## TRANSACTIONS OF IRE PROFESSIONAL GROUPS

**The following issues of Transactions are available from the Institute of Radio Engineers Inc., 1 East 79 Street, New York 21, N. Y., at the prices listed below.**

| Sponsoring Group | Publications | Group Members | IRE Members | Non-members* |
|---|---|---|---|---|
| Aeronautical & Navigational Electronics | PGAE-4: The Selectivity and Intermodulation Problem in UHF and Communication Equipment (11 pages) | $ .45 | $ .65 | $1.35 |
| | PGAE-5: A Dynamic Aircraft Simulator for Study of Human Response Characteristics (6 pages; | .30 | .45 | .90 |
| | PGAE-6: Ground-to-Air Co-channel Interference at 2900 Mc (10 pages) | .30 | .45 | .90 |
| | PGAE-8: June 1953 (23 pages) | .65 | .95 | 1.95 |
| | PGAE-9: September 1953 (27 pages) | .70 | 1.05 | 2.10 |
| | Vol. ANE-1. No. 1, March 1954 (51 pages) | 1.00 | 1.50 | 3.00 |
| Antennas and Propagation | PGAP-4: IRE Western Convention, August 1952 (136 pages) | 2.20 | 3.30 | 6.60 |
| | Vol. AP-1, No. 1: July 1953 (30 pages) | 1.20 | 1.80 | 3.60 |
| | Vol. AP-1, No. 2: October 1953 (31 pages) | 1.20 | 1.80 | 3.60 |
| | Vol. AP-2, No. 1: January 1954 (39 pages) | 1.35 | 2.00 | 4.05 |
| | Vol. AP-2, No. 2: April 1954 (41 pages) | 2.00 | 3.00 | 6.00 |
| | Vol. AP-2, No. 3: July 1954 (36 pages) | 1.50 | 2.25 | 4.50 |
| Audio | PGA-5: Design Interrelations of Records and Reproducers (8 pages) | .30 | .45 | .90 |
| | PGA-7: Editorials, Technical Papers and News, May 1952 (47 pages) | .90 | 1.35 | 2.70 |
| | PGA-10: November-December 1952 (27 pages) | .70 | 1.05 | 2.10 |
| | Vol. AU-1, No. 1: January–February 1953 (24 pages) | .60 | .90 | 1.80 |
| | Vol. AU-1, No. 2: March–April 1953 (34 pages) | .80 | 1.20 | 2.40 |
| | Vol. AU-1, No. 3: May–June 1953 (34 pages) | .80 | 1.20 | 2.40 |
| | Vol. AU-1, No. 4: July–August 1953 (19 pages) | .70 | 1.05 | 2.10 |
| | Vol. AU-1, No. 5: September–October 1953 (11 pages) | .50 | .75 | 1.50 |
| | Vol. AU-1, No. 6: November–December 1953 (27 pages) | .90 | 1.35 | 2.70 |
| | Vol. AU-2, No. 1: January–February 1954 (38 pages) | 1.20 | 1.80 | 3.60 |
| | Vol. AU-2, No. 2: March–April 1954 (31 pages) | .95 | 1.40 | 2.85 |
| | Vol. AU-2, No. 3: May–June 1954 (27 pages) | .95 | 1.40 | 2.85 |
| | Vol. AU-2, No. 4: July–August 1954 (27 pages) | .95 | 1.40 | 2.85 |
| Broadcast and Television Receivers | PGBTR-1: Round-Table Discussion on UHF TV Receiver Considerations, 1952 IRE National Convention (12 pages) | .50 | .75 | 1.50 |
| | PGBTR-2: General Color-Receiver Design Considerations and Connection of UHF & Color Adaptors to UHF Receivers (21 pages) | .60 | .90 | 1.80 |
| | PGBTR-3: June 1953 (67 pages) | 1.40 | 2.10 | 4.20 |
| | PGBTR-5: January 1954 (96 pages) | 1.80 | 2.70 | 5.40 |
| | PGBTR-6: April 1954 (119 pages) | 2.35 | 3.50 | 7.00 |
| | PGBTR-7: July 1954 (58 pages) | 1.15 | 1.70 | 3.45 |
| Circuit Theory | PGCT-1: IRE Western Convention, August 1952 (100 pages) | 1.60 | 2.40 | 4.80 |
| | PGCT-2: Papers Presented at the Circuit Theory Sessions of the Western Electronic Show and Convention, San Francisco, California, August 19–21, 1953 (106 pages) | 1.95 | 2.90 | 5.85 |
| | Vol. CT-1, No. 1: March 1954 (80 pages) | 1.30 | 1.95 | 3.90 |
| | Vol. CT-1, No. 2: June 1954 (39 pages) | 1.00 | 1.50 | 3.00 |
| Communications Systems | Vol. CS-1, No. 1: Includes papers presented at the Technical Conference on Communications (72 pages) | 1.50 | 2.25 | 4.50 |
| | Vol. CS-2, No. 1: January 1954 (83 pages) | 1.65 | 2.50 | 4.95 |
| Component Parts | PGCP-1; March 1954 (46 pages) | 1.20 | 1.80 | 3.60 |
| Electronic Computers | Vol. EC-2, No. 2: June 1953 (27 pages) | .90 | 1.35 | 2.70 |
| | Vol. EC-2, No. 3: September 1953 (27 pages) | .75 | 1.10 | 2.25 |
| | Vol. EC-2, No. 4: December 1953 (47 pages) | 1.25 | 1.85 | 3.75 |
| | Vol. EC-3, No. 1: March 1954 (39 pages) | 1.10 | 1.65 | 3.30 |
| | Vol. EC-3, No. 2: June 1954 (65 pages) | 1.65 | 2.45 | 4.95 |
| | Vol. EC-3, No. 3: September 1954 (54 pages) | 1.80 | 2.70 | 5.40 |

(*Continued on the following page*)

* Public libraries, colleges, and subscription agencies may purchase at IRE Member rate.

## PROFESSIONAL GROUP NEWS

### SCOPE OF PRODUCTION TECHNIQUES GROUP MODIFIED

The recently formed Professional Group on Production Techniques held an organizational meeting at IRE headquarters on September 27 and elected the following officers for the coming year: Chairman, R. R. Batcher; Vice-Chairman, J. R. Allen; Secretary, R. A. Gerhold.

During the meeting, the scope of the group was reviewed and modified in order to promote technical progress in the design and manufacture of electronic equipment by manual or automatic means. This will be done by collecting and distributing information on advances in methods, processes, materials and components. The information will include details on how to improve operating simplicity, reliability, and appearance of equipment by such means as miniaturization, encapsulation, circuit packaging and assembly techniques.

The scope of the new group will also include scientific, technical, and industrial areas that contribute to the field. The group's scope will be modified, as the field of production techniques develops, with the direction and approval of the IRE Committee on Professional Groups.

### FIVE NEW CHAPTERS APPROVED

The IRE Executive Committee, at a meeting on October 4, approved the establishment of five professional group chapters. They are: PG on Antennas and Propagation, Philadelphia; PG on Microwave Theory and Techniques, Philadelphia; PG on Microwave Theory and Techniques, Long Island; PG on Electron Devices, Washington; PG on Nuclear Science, Washington.

## TRANSACTIONS OF IRE PROFESSIONAL GROUPS (Continued)

| Sponsoring Group | Publications | Group Members | IRE Members | Non-members |
|---|---|---|---|---|
| Electron Devices | PGED-2: Papers on Electron Devices presented at IRE Conference on Electron Tube-Research, Ottawa, Canada June 16–17, 1952 and IRE Western Convention, Long Beach (84 pages) | $1.60 | $2.40 | $4.80 |
| | PGED-4: December 1953 (62 pages) | 1.30 | 1.95 | 3.90 |
| | Vol. ED-1, No. 1: February 1954 (72 pages) | 1.40 | 2.10 | 4.20 |
| | Vol. ED-1, No. 2: April 1954 (75 pages) | 1.40 | 2.10 | 4.20 |
| | Vol. ED-1, No. 3: August 1954 (77 pages) | 1.40 | 2.10 | 4.20 |
| Engineering Management | PGEM-1: February 1954 (55 pages) | 1.15 | 1.70 | 3.45 |
| Industrial Electronics | PGIE-1: August 1953 (40 pages) | 1.00 | 1.50 | 3.00 |
| Information Theory | PGIT-2: A Bibliography of Information Theory (Communication Theory-Cybernetics (60 pages) | 1.25 | 1.85 | 3.75 |
| | PGIT-3: March 1954 (159 pages) | 2.60 | 3.90 | 7.80 |
| | PGIT-4: September 1954 (234 pages) | 3.35 | 5.00 | 10.00 |
| Instrumentation | PGI-2: Data Handling Systems Symposium: IRE Western Electronic Show & Convention, Long Beach, California, August 27–29, 1952 (111 pages) | 1.65 | 2.45 | 4.95 |
| | PGI-3: April 1954 (55 pages) | 1.05 | 1.55 | 3.15 |
| Medical Electronics | PGME-1: November 1953 (40 pages) | 1.05 | 1.55 | 3.15 |
| Microwave Theory and Techniques | Vol. MTT-1, No. 2: November 1953 (44 pages) | .90 | 1.35 | 2.70 |
| | Vol. MTT-2, No. 1: Papers presented at the Microwave Radio Relay Systems Symposium, New York, N. Y.–April 1954 (107 pages) | 2.20 | 3.30 | 6.60 |
| | Vol. MTT-2, No. 2: July 1954 (67 pages) | 1.25 | 1.85 | 3.75 |
| | Vol. MTT-2, No. 3: September 1954, Papers presented at the joint IRE Professional Group–URSI meeting held in Washington, D.C. May 5, 1954 (54 pages) | 1.10 | 1.65 | 3.30 |
| Nuclear Science | Vol. NS-1, No. 1: September 1954 (42 pages) | .70 | 1.00 | 2.00 |
| Quality Control | PGQC-1: Papers presented at the 1951 Radio Fall Meeting, and 1952 IRE National Convention (58 pages) | 1.20 | 1.80 | 3.60 |
| | PGQC-2: March 1953 (51 pages) | 1.30 | 1.95 | 3.90 |
| | PGQC-3: February 1954 (39 pages) | 1.15 | 1.70 | 3.45 |
| Radio Telemetry and Remote Control | PGRTRC-1: August 1954 (16 pages) | .85 | 1.25 | 2.55 |
| Ultrasonics Engineering | PGUE-1: June 1954 (62 pages) | 1.55 | 2.30 | 4.65 |
| Vehicular Communications | PGVC-2: Symposium on What's New in Mobile Radio (32 pages) | 1.20 | 1.80 | 3.60 |
| | PGVC-3: Theme: Spectrum Conservation, Washington, D. C., December 3–5, 1952 (140 pages) | 3.00 | 4.50 | 9.00 |
| | PGVC-4: Design, Planning and Operation of Mobile Communications Systems June 1954 (98 pages) | 2.40 | 3.60 | 7.20 |

* Public libraries, colleges, and subscription agencies may purchase at IRE Member rate.

## TECHNICAL COMMITTEE NOTES

On September 16th the **Standards** Committee convened under Vice-Chairman Baldwin. R. F. Shea, chairman of the *ad hoc* committee on Spurious Radiation reported that a meeting had been held on September 15. A number of technical committees were represented. Mr. Shea noted that interest in spurious radiation was industry-wide and that the IRE had been encouraged to furnish standards as soon as possible. The following action was taken: all technical committees involved will prepare reports on this field. The Measurements and Instrumentation Committee will enlarge the subcommittee on Interference Measurements to include members from other technical committees and will prepare a basic standard on interference measurements. Interested technical committees will nominate people to serve on RETMA task forces; technical committees will then work up specific standards as required by the task forces; JTAC, through A. V. Loughren, will advise the Standards Committee of additional work needed in fields where there is no corresponding technical committee. It was noted that RETMA plans to make a report to the FCC in January on the progress of their work. A report on the IEC Golden Jubilee meeting in Philadelphia was made by R. F. Shea and J. G. Brainerd. Mr. Anspach reported for the Symbols Committee on a symbol for the new term "decilog." A number of Navigation Aids definitions were considered by the committee.

The **Antennas and Waveguides** Committee met on September 15 with P. H. Smith presiding. The chairman reviewed the membership of the present committee and the various subcommittees and reported on correspondence with the West Coast Subcommittee 2.3. E. T. Jaynes agreed to serve as chairman of this subcommittee and as a member of the main committee. It was suggested at a subcommittee meeting that, in addition to their guide to the literature of waveguide theory and techniques, the subcommittee begin a similar guide in the antenna domain. Mr. Smith tentatively approved this task and asked that the subcommittee consider modernization of the Standards on Methods of Testing Antennas. Approval of the *IRE Standards on Antennas and Waveguides: Definitions of Terms*, 1953 by the American Standards Association was announced. A Definitions Review Committee of the Standards Committee submitted their comments on the definitions of Waveguide Components, which were agreed to by the Standards Committee.

On September 10, the **Facsimile** Committee met under the chairmanship of Henry Burkhard. L. R. Lankes made suggestions on preparation of a test chart and recommended films to use. A test chart made from the National Bureau of Standards Chart had been mailed to various members, and comparisons were made between this and the Tapered Line Wedge. Mr. Klyce submitted samples of 200 and 300 line Lithure offset printing and photographic facsimile recordings. During the remainder of the meeting definitions of terms were considered.

The **Feedback Control Systems** Committee met on September 9th with R. B. Wilcox presiding. G. A. Biernson reported on the last meeting held by ASA Committee Y10.14. G. S. Axelby reported on definitions of terminology for feedback control systems as given by the AIEE, ASME, IRE and ASA Y10.14; he pointed out that in many instances the terminology for words with similar meanings is quite different, but in other instances, the same term has different meanings. Mr. Axelby volunteered to continue his research and to prepare a dictionary of feedback control system terminology. The committee decided to discuss proposed definitions before passing them on so that discussions would be included in the minutes and thus aid the subcommittee in its development of definitions. Enclosed with a letter from Dr. Ernest Weber, chairman of the Standards Committee, was a list of proposed entries to the Master Index of Measurements. The committee discussed these terms. Dr. Weber will be queried on what is desired in this list. After definitions by S. B. Williams and G. A. Biernson were examined, the committee discussed how to measure frequency response.

On September 17 the **Navigation Aids** Committee met under the chairmanship of H. R. Mimno. The committee considered several questions raised by the Standards Committee with reference to recently proposed definitions. The committee examined and approved sections of a revised manuscript on radio direction finding. The editorial group was asked to continue its work on remaining sections of the original manuscript and to consider further suggestions on minor changes in the revised copy.

# CONFERENCE ON HIGH FREQUENCY MEASUREMENTS

Sponsored Jointly by IRE, AIEE, NBS, and URSI
Statler Hotel, Washington, D. C. January 17–19, 1955

## Monday, January 17

**9:30 A.M. Registration**

**1:30 P.M.—Technical Session I**

### Measurement of Transmission and Reception

*Presiding:* B. Parzen, Olympic Radio & Television Co.

"Measurements and Components for Rectangular Multimode Waveguides," D. J. Angelakos, Electronic Research Laboratory, University of California.

"A Comparison Method for Tuning Wideband TR Tubes," Herbert H. Rickert, Wheeler Laboratories, Inc.

"Radio Interference Measurement Techniques," Leonard W. Thomas, Bureau of Ships, Navy Department.

"Pattern Measurements of Large Fixed Antennas," J. P. Shanklin, Collins Radio Co.

"Accurate Radar Attenuation Measurements Achieved byIn-Flight Calibration" F. J. Janza and R. E. West, Sandia Corporation.

"Use of Distribution Curves in Evaluating Microwave Path Clearance," B. F. Wheeler and H. R. Mathwich, RCA Electronic Products Division.

## Tuesday, January 18

**9:30 A.M.—Technical Session II**

### Measurement of Power and Attenuation

*Presiding:* E. W. Houghton, Bell Telephone Labs.

"6 KMC Sweep Oscillator," D. A. Alsberg, Bell Telephone Labs.

"Data on Temperature Dependence of X-Band Fluorescent Lamp Noise Sources" W. W. Mumford and R. L. Schafersman, Bell Telephone Labs.

"Broadband UHF and VHF Noise Generators," W. H. Spencer and P. D. Strum, Airborne Instruments Laboratory.

"A Noise Meter Having Large Dynamic Range," P. D. Strum, Airborne Instruments Laboratory.

"Precise Insertion Loss Measurements Using Imperfect Square Law Detectors and Accuracy Limitations Due to Noise," Bruno O. Weinschel, Weinschel Engineering Co., Inc.

"Microwave Peak Power Measurenent Techniques," R. E. Henning, Sperry Gyroscope Company.

**12:15 P.M.—Luncheon**

*Presiding:* R. V. Lowman, Chairman, Joint AIEE-IRE Committee on High Frequency Measurements

The Honorable Donald A. Quarles, Assistant Secretary of Defense for Research and Development, guest speaker.

**2:00 P.M.—Inspection Trip**

(Chartered buses leave from Hotel Statler)
Bureau of Standards
Naval Observatory
Naval Ordnance Laboratory*
Naval Research Laboratory*

**8:15 P.M.—Demonstration Lectures**
**Interior Department Auditorium**

This evening session is sponsored jointly by the Conference Committee and the Washington Sections of the AIEE and IRE.

*Presiding:* J. W. Kearney, Airborne Instruments Laboratory

"Engineers Are People," George H. Brown, Systems Research Laboratory, R.C.A.

"An Excursion in Electronics," Cyril N. Hoyler, Technical Relations, R.C.A.

## Wednesday, January 19

**9:30 A.M.—Technical Session III**

### Measurement of Impedance

*Presiding:* A. A. Oliner, Polytechnic Institute of Brooklyn

"Application of UHF Impedance Measuring Techniques in Biophysics," Herman P. Schwan, Moore School of Electrical Engineering, University of Pennsylvania.

"Representation and Measurement of a Dissipative Four-Pole by Means of a Modified Wheeler Network," H. M. Altschuler, Microwave Research Institute, Polytechnic Institute of Brooklyn.

"The Use of Concentric-Line Transformers in UHF Measurenents," W. A. Harris and J. J. Thompson, R.C.A.

"Figure of Merit of Probes as Standing Wave Detectors," S. W. Rubin Polytechnic Research and Development Corp. and M. Wind, Microwave Research Inst., Polytechnic Institute of Brooklyn.

"Characteristics of Microwave Comparators," E. W. Matthews, Sperry Gyroscope Co.

"A Comparison Method for Measuring Cavity Q," E. B. Mullen and P. M. Pan, General Elec. Co.

**2:00 P.M.—Technical Session IV**

### Measurement of Frequency and Time

*Presiding:* B. M. Oliver, Hewlett-Packard Co.

"A Portable Frequency Standard for Navigation," P. Antonucci, Rome Air Development Center, J. O. Israel, E. B. Mechling, and F. G. Merrill, Bell Tel. Labs.

"Locked Oscillators in Frequency Standards and Frequency Measurements," J. K. Clapp, General Radio Co.

"Measurement of the RF Frequency of RF Pulses," A. Bagley and D. Hartke, Hewlett-Packard Co.

"An Instrument for Precision Range Measurements," D. H. Beck, Hazeltine Electronics Corp.

"6 KMC Phase Measurement System for Traveling Wave Tubes," C. F. Angustine and A. Slocum, Bell Telephone Labs.

"A Precision X-band Phase Shifter," E. F. Barnett, Hewlett-Packard Co.

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* Restricted to citizens of the U.S.A.

# Abstracts of Transactions of the I-R-E

**The following issues of "Transactions" have just been published, and are now available from The Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y. at the following prices. The contents of each issue and, where available, abstracts of technical papers are given below.**

| Sponsoring Group | Publication | Group Members | IRE Members | Non-Members* |
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| Circuit Theory | Vol. CT-1, No. 4 | $1.15 | $1.70 | $3.45 |
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| Nuclear Science | Vol. NS-1, No. 1 | 0.70 | 1.00 | 2.00 |

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## CIRCUIT THEORY

### Vol. CT-1, No. 4, December, 1954

**Editorial on Nonlinear Filters—W. D. White**

**Analysis of Multi-Loop Nonlinear Systems —Y. H. Ku**

In many multi-loop nonlinear systems, it is possible to get from the original set of simultaneous differential equations a single differential equation of a higher order. The high order nonlinear differential equation can be solved by an n-dimensional phase-space method, which is an extension of the phase-plane method. As an illustration, a three-loop system is analyzed. Numerical examples for a two-loop system with nonlinear elements either in one of the loops or in the coupling are also given. Two-dimensional trajectories are shown as projections of phase-space trajectories.

**Steady-State Oscillations in Non-Linear Multi-Loop Circuits—K. Klotter**

This paper treats the analysis of nonlinear systems having more than a single degree of freedom. The method used is the Ritz or Ritz-Galerkin method that has been extensively applied to statical problems in elasticity and to eigenvalue problems of various types. Until very recently, however, it has rarely been applied to dynamical problems other than eigenvalue problems. As shown by some specific examples, the method proves to be a powerful one for the purposes at hand.

**Communication Theory and Cybernetics—D. Gabor**

In the case of band-limited signals, the sampling theorem permits us to replace analytic operations with algebraic operations. We are then able to discuss problems of measurement of information, coding, and transmission over noisy channels in terms of discrete samples, rather than continuous time functions. The design of the optimum linear filter reduces from a very difficult analysis problem involving spectrum factorization to a straightforward problem of solving a set of simultaneous linear equations. Unless we are interested in the most economical implementation, it is not even necessary to solve the equations, since a synthesis procedure involving only simple functions of the correlation functions is available. When extended to the general nonlinear case, the design is still specified by a set of simultaneous algebraic equations, but the labor of solution grows very rapidly. It is proposed to short-circuit this labor by building a learning filter which in effect designs itself. A training period in which the adjustments are automatically optimized precedes the use period. By modifying the training program, it is possible that the filter could be taught to recognize specific signals, including, perhaps, certain speech sounds.

**The Measurement and Representation of Non-Linear Systems—R. C. Booton, Jr.**

Measurements of the response of a nonlinear system to one or more inputs can be used to obtain an approximate mathematical statement of the way in which the response depends upon the input. Such a statement can be used to predict the response of the system to inputs other than those used in the measurements. A general approach is presented in which the response is approximated by a linear combination of responses of known systems. The coefficients in this combination are the parameters that are to be determined. Choice of these parameters to minimize the mean-square value of the difference between the linear combination and the actual response is shown to lead to a set of equations that are linear in the system parameters. The quantities that must be measured are the values of the cross-correlation of the response with the responses of the known systems. Methods proposed by Singleton and Weiner are presented as specific examples. Methods more general than the least-mean-square approach are described briefly. The criteria by which any of these measurement and characterization procedures can be evaluated are discussed.

**Erratum: Approximating Band-Pass Attenuation and Phase Functions—V. Grinich**

Reviews and Abstracts

Chapter News

## COMPONENT PARTS

### PGCP-2, September, 1954

**WESCON Component Parts Sessions Program**

**WESCON Component Parts Technical Papers Committee**

**Short Time Ratings for Paper Capacitors (Abstract)—W. M. Allison**

The present basis for rating dc and ac paper capacitors for long life is reviewed. Probability of failure at higher voltages than rated as a function of magnitude and duration of voltage, number of applications of voltage, capacitance, and temperature are discussed. Comments on application of paper capacitors are included.

**Rotating Components and Their Application to Advanced Electronic Systems (Abstract) —R. N. Brown**

The broad field of rotating components as applied to advanced electronic systems is surveyed. Types of components are analyzed from the viewpoint of the system designer. Typical equivalent circuits are presented as well as charts intended to facilitate selection and evaluation of the proper component for a given application. The effect of the component in the system is treated from both the viewpoint of the designer and the user. Physical factors which limit higher and higher performance and wider ranges of ambient conditions are presented as well as the efforts which are being made today to overcome these limitations. Finally, the newest advances in the rotating component art are discussed in light of their impact on system design and performance.

**Appraisal of Wirewound Potentiometers—J. A. Csepely**

The general construction of rotary and rectilinear types of low power potentiometers and rheostats is described, and the basic requirements for obtaining adequate performance life are enumerated. The following points are discussed: effects of brush contact pressure, brush lead-off wires versus brush commutator design, potentiometer windings wound on round mandrels and on thin cards, binding materials, ways of measuring brush contact noise, methods of obtaining non-linear functions, winding resolution on brush and potentiometer wire wear, wear on the brush contact vs. wear on the potentiometer wire, methods which have been used to seal potentiometer enclosures against the effects of the environments, replacement problems on multiple cup units, plug-in type potentiometers and the possible effects of electrolysis between a metallic housing and the potentiometer winding.

**Relay Characteristics and Application—C. F. Cameron**

Knowledge of relay characteristics is essential if the different relay types are to be applied correctly, specified correctly, and used correctly. Vacuum tube characteristics are compared to those of a relay and it is found that the relay characteristics are more complicated. A discussion is given of the non-linear relations which exist in the coil circuit. The mechanical moving parts also show a non-linear force-distance relationship. No exact solution has been found for either case.

Circuit constants of the coil circuit influence relay operation with rated coil voltage or current. To a minor extent, the circuit constants may cause unwanted disturbances in the contact circuit.

When changes in environmental conditions, such as temperature, occur an added complication takes place which also influences the relay characteristics. Military conditions require more attention to details of application, specification, and usage.

**A Precise, Wide-Band, Continuously Variable Delay Line—N. Gaw, M. Kline and D. Silverman**

A continuously variable delay line, capable of precise delay settings with faithful transmission of pulse signals, is described. Lines having maximum delays of 0.1 to 0.5 microseconds and impedances up to 1300 ohms have been built, and lines having delays of 1 microsecond or more are practical. A typical line has a total delay time of 0.2 microsecond, an impedance of 1050 ohms, and a rise time of 0.01 microsecond. The resolution of this variable delay line enables settings to better than 0.1% of total delay, equivalent to a precision of 0.2 millimicrosecond. Lines built to date have exhibited negligible overshoot or phase distortion.

Design problems concerning terminations and elimination of distortions are discussed.

**The User Looks at the Component Parts Problem—A. M. Okun**

Much information has been given on component parts from the military standpoint and from the manufacturers' point of view. However, the contractor of military equipment is placed in the unique position of selling the component parts manufacturers' claims to the military customer.

The component parts problems encountered by users can be summarized into three categories:

1. Problems caused by users themselves.
2. Problems caused by parts manufacturers.
3. Problems caused by military agencies.

It is proposed to discuss some methods by which a coordinated effort by the three groups concerned with the use of component parts could increase reliability of complex electronic equipment.

**Packaging of Component Parts for High Intensity Vibration Environments—M. G. Comuntzis**

This paper deals with mechanical design principles and packaging techniques which enable electronic components to withstand severe vibration environments without failure. Observation of equipment with conventional construction techniques reveals that mechanical amplifications of component part mountings subject component parts to vibration levels many times those applied. Laboratory tests show that vibration levels of 20 to 30 g are not damaging to reliable parts, but failures result when mechanical resonances subject component parts to 100 and 200 g.

The techniques presented in this paper depart radically from conventional practices. Lantern slides, diagrams, and hardware have been used to illustrate how vibration reliability can be achieved without sacrifice of weight, volume, or accessibility.

**Electrostrictive Relay—J. W. Crownover**

This paper deals with the operating principle of the Mullenbach nonmagnetic relay, the Capaswitch.

The electrostrictive effect of barium titanate ceramic is utilized as the actuating element. It consists of a beam of ceramic 3″ long by ½″ wide by .01″ thick, which is supplied with adequate electrodes over the largest parallel surfaces and attached to a nickel iron member possessing the same physical dimensions and thermal coefficient. This ceramic and metal bi-element will bend in proportion to the amplitude of a potential applied across the electrodes of the ceramic strip.

The motion, u, realized is expressed as: $u = SL^2/t$ where $S$ is the strain coefficient and includes the piezo electro modulus. The resulting force, $F$, obtained is expressed as: $F = SYt^2b/4L$.

A force of 20 gms may be realized through a motion of .005″. Thermal and mechanical problems of stability are discussed such as the type of beam support and snap action springs used.

Possible future relays of greater power and sensitivity are discussed.

**A Temperature Stabilized Transistor Amplifier—R. B. Hurley**

The detrimental effects of temperature upon the performance of germanium transistors is discussed. The temperature problem is then evaluated for the specific case of a grounded-emitter amplifier using junction transistors. The choice of a transistor type is treated. Criteria for dc circuitry and additional ac techniques are then developed for the temperature stabilization of transistor amplifiers.

Design objectives for several amplifiers are established. The experimental results for a number of designs are presented and discussed. Conclusions are then drawn to the effect that properly designed amplifiers employing junction transistors can operate over a temperature span of two hundred degrees Fahrenheit with voltage gain variations of only a few per cent. This temperature stabilization is indicated as being possible without the use of complicated circuitry.

**Reliable Electronics Through Protective Coating Techniques—E. R. Gamson and A. Henesian**

Stanford Research Institute has been engaged in a program involving studies and methods of protective coating materials. The techniques investigated, including thin coatings, cast-resin embedment, and foam-plastic encapsulation, were found to offer effective methods for improving the reliability of electronic systems. The protective medium surrounding such equipment could, in the ideal sense, eliminate failures due to vibration, moisture, or other environmental effects.

The results of these studies indicate the degree of protection now offered and the direction in which the ideal may be obtained. Our research indicates that it is now possible to operate critical electronic devices in adverse environmental conditions for extended periods, by the application of the correct protective coating system.

## NUCLEAR SCIENCE

### Vol. NS-1, No. 1, September, 1954

**Editorial**

**Instrumentation and Control of the Brookhaven Nuclear Reactor—J. E. Binns**

Safe startup and operation of the nuclear reactor require neutron-sensing instruments to cover a range of about $10^9$. This coverage is obtained by a counting rate meter, a period meter, and a high level power indicator. At normal operating levels, the reactor is regulated by the high level power controller and protected by the high level trips.

Emergency shutdown of the reactor can be initiated by any one of 54 different conditions. Since these safety circuits are almost 100% "fail safe," careful design, good maintenance, and cautious operation have been necessary to avoid accidental shutdowns.

The period trips and high level trips are provided in triplicate for safety and are coincidence-connected in pairs to guard against accidental shutdown. The use of suppressed-zero circuits has proved helpful. The theory of coincidence connected trips is briefly discussed.

**Constant Reactor Outlet Temperature Control System for Nuclear Power Plants—G. S. Stubbs**

The problem of designing a constant reactor outlet temperature control system for a thermal reactor power plant is considered. The dynamic control characteristics of the power plant are described in terms of (1) the response of reactivity to variations of reactor inlet coolant temperature, (2) the heat transfer characteristics of the reactor and boiler, and (3) the time lags of the reactor coolant loop. It is shown how the inherent characteristics of the power plant may be used to advantage by constant reactor outlet temperature control systems employing the reactor inlet and outlet temperatures as control variables. An important feature of these control systems is the computation of the reactor inlet temperature from the boiler outlet temperature or the steam plant variables using recently developed transport delay circuits to compensate for the boiler-to-reactor coolant transport delay.

**Electronic Equipment for an Electron Analogue Accelerator—J. G. Cottingham, M. Plotkin and E. C. Raka**

An electron analogue accelerator 45 feet in diameter is being constructed to test a variety of orbital properties of a strong-focusing synchroton system. High-voltage saw-tooth wave generators will supply the electrostatic bending and correcting lenses. A feed-back type radio frequency control and power amplifier supply a simple low-$Q$ ferrite accelerating cavity. The rf control is designed to accommodate the phase stability transition encountered in strong-focusing synchrotrons. Auxiliary electronic systems will detect, observe, and time the circulating electron beam.

**Program of the Annual National Meeting, Chicago, October 6–7, 1954**

**Abstracts of Contributed Papers for Annual Meeting**

**Annual Report of the Secretary**

**Revised Constitution of the PGNS**

**By-Laws**

**Publication Policy**

**Selections from "Nuclear Science Abstracts"**

## MICROWAVE THEORY AND TECHNIQUES

### Vol. MTT-2, No. 3, September, 1954

### (Papers presented at IRE-URSI meeting, Washington, D. C., May 5, 1954)

**An Optical Method for the Measurement of Complex Dielectric and Magnetic Constants at Millimeter Wavelengths—T. E. Talpey. (Abstract)**

A method is described which permits the determination of the complex dielectric constant, $\epsilon^* = \epsilon_0 k_e\ (l - j \tan \delta_e)$, and the complex permeability, $\mu^* = \mu_0 k_m\ (l - j \tan \delta_m)$, using free space transmission and reflection from a plane sheet of the sample dielectric. The procedure represents an extension of that used at optical frequencies. Differences arise, however, due to the fact that the assumptions of $k_m = 1$ and $\tan \delta_m = 0$, which are made in the optical theory, are not always valid at millimeter wavelengths.

A measurement of the Brewster angle, or the angle of incidence which results in minimum reflection of a parallel-polarized wave, together with a measurement of the reflection coefficient for a perpendicularly polarized wave incident at the same angle, will permit the determination of the two quantities, $k_e$ and $k_m$. Measurement of the transmission coefficient with incidence at the Brewster angle, together with a measurement of the ratio of the reflection coefficients with parallel and perpendicular polarizations (at the Brewster angle), will allow $\tan \delta_e$ and $\tan \delta_m$ to be determined.

A method of handling the experimental data to correct for multiple reflections within the sample is presented, and the effect of losses on the determination of $k_e$ and $k_m$ is discussed. These considerations indicate that the method in its present form can be applied only to those materials for which $\tan (\delta_e + \delta_m)$ is less than 0.1.

The experimental equipment described includes a Klystron for generating eight millimeter waves, a coaxial wavemeter which permits determination of the wavelength to 0.01 millimeter, a calibrated cut-off attenuator, and a special crystal detector. The mechanical arrangement permits adjustment and accurate measurement of the angle of incidence, as well as change of polarization by rotation of the horn antennas.

A discussion of experimental results concludes the paper.

**Millimeter Wave Spectroscopic Components—W. C. King.**

The history of millimeter-wave generation and detection is reviewed briefly with particular emphasis upon developments affecting microwave molecular spectroscopic research. Crystal harmonic generators capable of producing detectable amounts of radiation at twelfth harmonic when driven by a 1.25 cm reflex klystron are described in detail. Broad band video detectors having exceptional sensitivity are also described.

A tuning technique obviating the necessity for high-pass filtering in harmonic generator spectrographs has been developed which greatly simplifies work at the very short wavelengths. Molecular resonance absorptions of linear and symmetric top molecules are very nearly, but not exactly, harmonically related. Their use in a sweep spectroscope gives an immediate indication of the presence or absence of a particular harmonic in the output of the generator and permits rough estimates of the relative amounts of power in the several harmonics which may be present simultaneously.

Some recent spectroscopic measurements at wavelengths shorter than two millimeters are given, and the possibility of using molecular resonances as secondary standards of frequency is discussed.

**Harmonic at Millimeter Wavelengths—A. H. Nethercot, Jr.**

Magnetrons emit harmonics of their fundamental frequency and these have been detected up to the tenth harmonic of 1.25 cm. The techniques involved, the results, and the limitations are discussed.

Crystal frequency multipliers which operate with driving power from K-band klystrons and have given up to eighth harmonic is also discussed. Their conversion loss as a function of input power, harmonic number and contact pressure is described.

The crystal detectors used can detect $\frac{1}{2}\times 10^{-9}$ watts at 1.5 mm with a bandwidth of 1 cps. This is 300 times worse than 10 cm detectors.

**Millimeter Wave Generation by Cerenkov Radiation—M. Danos, H. Lashinsky, and C. H. Townes.**

The two main obstacles in extracting high frequency energy from an electron beam are (1) the necessity of having the coupling structure very close to the beam, and (2) the difficulty of building a sufficiently small mechanical structure. The second obstacle is avoided when using Cerenkov radiation. Therefore, an experiment has been undertaken to detect Cerenkov radiation at microwave frequencies.[1] A power of roughly $10^{-7}$ W was observed at K-band, in reasonable agreement with theoretical estimates. The interaction between the electron beam and the radiation field is very small because the energy of the radiation is contained mainly inside of the dielectric and the energy density at the location of the electron beam is small. This to a certain extent can be overcome by reflecting the radiation back to the electron beam and thus increasing the energy density there. The radiated power then increases proportionally to the number of times the radiation has been or can be reflected back to the beam, i.e., to the $Q$ of the system. The prospects of obtaining radiation of about 1 mm with realizable arrangements is discussed.

**Stabilization of Reflex Klystrons by High-*Q* External Cavities—S. J. Rabinowitz**

The frequency stability of millimeter reflex klystrons is extremely poor. This paper describes a means of stabilizing a klystron to an external cavity without the use of electronic circuitry. The method consists of coupling a high-$Q$ cavity to the klystron and, by this means, raising the effective $Q$ of the tube. The system is simple to build and align, and the combination of klystron and stabilization cavity can be tuned over the entire frequency range of the klystron. Stabilization ratios as high as 10 are readily achievable. The results of stabilizing a $k$-band (1.25 cm) 2$k$33 klystron and a $k_a$-band (9 mm) $QK$290 klystron in this manner are presented.

**Superheterodyne Receiver for the 100 to 150 KMC Region—C. M. Johnson**

A superheterodyne receiver system has been developed to work in the frequency range from 100 to 150 kmc. In this region there are no oscillators available, and the powers obtainable from harmonic generators are less than required for efficient mixing. However, by mixing, for example, the harmonic signal at 100,000 mc from the transmitter oscillator with the fundamental signal at 25,010 mc from the local oscillator to obtain a 40 mc IF frequency, it is possible to obtain an increase in insensitivity of 30 db or more over a crystal video receiver. The components of this system are described, and performance data are given.

**Magnetron Research at Columbia Radiation Laboratory—M. J. Bernstein and N. M. Kroll**

The principal objective of magnetron research at Columbia Radiation Laboratory has been the exploration of the possibilities of magnetrons in the millimeter wave length region.

Research with conventional pulsed magnetron structures has been directed towards the production of the shortest wavelengths, the development of higher power tubes at the longer millimeter wavelengths, and the development of wide range mechanical tuning schemes. Results achieved will be presented.

In addition, a program for the investigation of low magnetic field operation of magnetrons has been carried out. Results obtained have been encouraging in connection with millimeter wave applications and will be discussed.

**Low Loss Dielectric Waveguides—M. T. Weiss and E. M. Gyorgy**

After a short historical survey, a brief discussion of the general theory of dielectric waveguides is presented. It is then shown that the hybrid $HE_{11}$ mode on a rectangular or oval dielectric line is the best choice for low loss dielectric waveguide transmission. Experimental attenuation measurements made at 24,000 and 48,000 mc, using both a direct long line measurement technique and a resonator method, are presented. Launching, shielding, and support problems are discussed.

**An Experimental Broad-Band Helix Traveling-Wave Amplifier for Millimeter Wavelengths—S. D. Robertson. (Summary)**

This paper describes the design and performance of a helix traveling-wave amplifier which has been operated successfully in the millimeter-wave region. Amplifications of as much as 19 db have been obtained at a wavelength of 6 millimeters. Amplifications of 9 db have been measured at wavelengths as short as 5.2 millimeters.

**A Calorimeter for Power Measurements at Millimeter Wavelengths—W. M. Sharpless**

A calorimeter for measuring low-level power at millimeter wavelengths is described. This is a broadband device capable of measuring power levels of the order of one milliwatt with an estimated accuracy of plus or minus $\frac{1}{4}$ db. The calorimeter utilizes the substitution principle by matching the temperature rises of two identical power absorbers, in one of which is dissipated the unknown high frequency power while the other is heated by a measured amount of direct current power.

**The Use of Flat Waveguide in the Millimeter Range—S. Hopler (Abstract)**

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[1] M. Danos, S. Geschwind, H. Lashinsky, A. van Trier, *Phys. Rev.*, vol. 92, p. 828; 1953.

# Abstracts and References

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research, London, England, and Published by Arrangement with that Department and the *Wireless Engineer*, London, England

**NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the I.R.E.**

**Acoustics and Audio Frequencies** 1822
**Antennas and Transmission Lines** 1823
**Automatic Computers** 1824
**Circuits and Circuit Elements** 1824
**General Physics** 1826
**Geophysical and Extraterrestrial Phenomena** 1826
**Location and Aids to Navigation** 1828
**Materials and Subsidiary Techniques** 1828
**Mathematics** 1830
**Measurements and Test Gear** 1830
**Other Applications of Radio and Electronics** 1831
**Propagation of Waves** 1832
**Reception** 1833
**Stations and Communication Systems** 1833
**Subsidiary Apparatus** 1833
**Television and Phototelegraphy** 1834
**Transmission** 1834
**Tubes and Thermionics** 1835
**Micellaneous** 1837

**The Index to the Abstracts and References published in the PROC. I.R.E. from February 1953 through January 1954 is published by *Wireless Engineer* and included in the March 1954 issue of that journal. Copies of this issue may be purchased for $1 (including postage) from the Institute of Radio Engineers, 1 East 79th Street, New York 21, N.Y. As supplies are limited, the publishers ask us to stress the need for early application for copies. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.**

The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

A new section has been introduced covering the general technique of electromagnetic waves, oscillations and pulses (i.e. transmission lines and circuits), as distinct from specific applications to telecommunications. The new section is numbered 621.37, with subdivisions. Full details of the new classification, and of the numbers which become obsolete as a result of its introduction, are given in PE Note 535, obtainable from The International Federation for Documentation, Willem Witsenplein 6, The Hague, Netherlands, or from The British Standards Institution, 2 Park Street, London, W.1., England.

Section 621.396.67, dealing with Antennas, has been modified and expanded; details of the new classification are given in PE Note 519.

Section 621.396.96, with subdivisions, has been introduced to cover Radar; details of the new classification are given in PE Note 518.

New Subject Section

A section headed Automatic Computers has been introduced.

## ACOUSTICS AND AUDIO FREQUENCIES

**534.2** **3105**
**Variational Principles for the Acoustic Field**—E. Gerjuoy and D. S. Saxon. (*Phys. Rev.*, vol. 94, pp. 1445–1458; June 15, 1954.) "Variational principles are presented for the scattering amplitude in the general acoustic scattering problem, and, for spherically symmetric scatterers, for the phase shifts. Integral equations for the acoustic field are also given and the properties of the scattering matrix are developed. The entire formulation remains valid in the presence of discontinuities of density and/or velocity in the medium."

**534.321.9** **3106**
**Proposal for Standardization of the Expression for the Power delivered by an Ultrasonic Source**—M. Degrois. (*Ann. Télécommun.*, vol. 9, pp. 99–102; April, 1954.) The advantages of defining ultrasonic energy in terms, not of the total surface area of the radiator, but of the active area, are pointed out.

**534.41** **3107**
**Applications of Sound Spectrography in Acoustics Research**—W. Kallenbach. (*Akust. Beihefte*, no. 1, pp. 403–407; 1954.) Equipment based on the same principle as that of Koenig et al. (3517 of 1946) is described, and spectrograms are shown illustrating the time and frequency distributions of energy in sounds characteristic of bells, trains, motorcar engines and ball bearings.

**534.6:534.321.9** **3108**
**Pulse Apparatus for Measuring Absorption and Phase Velocity of Ultrasonic Waves in Liquids. Measurements on Liquid Naphthalene**—G. Busch and W. Maier. (*Z. Phys.*, vol. 137, pp. 494–502; May 8, 1954.) The accuracy obtainable using the interferometer apparatus described is within 0.1 per cent for velocity determinations and within 1 per cent for absorption-coefficient determinations. Attenuation is determined from a compensating adjustment of a calibrated attenuator, velocity from the observed wavelength and the known frequency. An oscilloscope is used as indicator. A frequency of 12 mc was used in the experimental determination.

**534.614:534.321.9** **3109**
**A Combined Time- and Phase-Modulation Method for Measurement of Sound Velocities using Commercial Ultrasonic-Pulse Equipment**—H. Schmauch and W. Bentz. (*Z. angew. Phys.*, vol. 6, pp. 168–171; April, 1954.) The calibrated variable-length liquid delay line is briefly described and an account is given of its application in an interference method of determining the velocity of sound.

**534.75** **3110**
**The Threshold of Audibility for Sounds with Frequency Spectrum of Various Widths**—G. Gässler. (*Akust. Beihefte*, no. 1, pp. 408–414; 1954.) When the sound components occupy a bandwidth less than a critical value called the coupling bandwidth, the sound-pressure level required for a complex sound to be just audible decreases as the number of components is increased. A complex sound will be just audible if within any coupling bandwidth the acoustic power is that which a single sine wave must have in order to be just perceptible.

**534.75** **3111**
**The Masking of Narrow-Band Noise by Sine Waves**—E. Zwicker. (*Akust. Beihefte*, no. 1, pp. 415–420; 1954.) Two sine waves with various frequency differences were superposed on white noise of the same frequency range. Regions of constant and variable masking were observed, independent of sound-pressure level, the critical frequency difference being about 90 cps up to a mean frequency of 500 cps and, above that, about 20 per cent of the mean frequency.

**534.75** **3112**
**The Problem of the Accuracy of Hearing of Persons with Impaired and Normal Hearing in the Presence of Traffic Noise**—F. J. Meister. (*Akust. Beihefte*, no. 1, pp. 421–427; 1954.)

**534.78:621.395.625.3** **3113**
**A Speech-Waveform Correlator with Magnetic-Tape Delay and Electronic Multiplication**—J. N. Holmes and J. M. C. Dukes. (*Proc. IEE*, part III, vol. 101, pp. 225–237; July, 1954.) An instrument designed to compute the auto- and cross-correlation functions of speech sounds having a duration <10 seconds.

**534.8** **3114**
**Normal-Frequency Statistics and Excitation Statistics [of normal modes] in Rooms**—M. Schröder. (*Akust. Beihefte*, no. 1, pp. 456–468; 1954.) Measurements were made on em cavity resonators; the results are interpreted for acoustic waves. In general the distribution both for normal-frequency spacing and for excitation of normal modes is a random one for fairly large rooms.

**621.395.61/.62** **3115**
**Uniform Electrical-Equivalent-Circuit Diagrams for Electroacoustic Transducers**—R. Feldtkeller and W. Nonnenmacher. (*Arch. elekt. Übertragung*, vol. 8, pp. 191–196; May, 1954.) Equivalent circuits based on the analogy between force and voltage are presented. Gyrators are included in the circuits corresponding to electrodynamic and magnetic transducers to indicate that these do not obey the law of inversion.

**621.395.61** **3116**
**A New Microphone with High Directivity**—K. Tamm and G. Kurtze. (*Akust. Beihefte*, no. 1, pp. 469–470; 1954.) See 1982 of August.

**621.395.623.7** **3117**
**Mechanical Transients in the Electrodynamic Loudspeaker**—N. Mayer. (*Funk u. Ton*, vol. 8, pp. 239–243; May, 1954.) An equivalent-circuit analysis shows how the time constant of transient vibrations occurring on sudden excitation of a moving-coil loudspeaker can be calculated from the electrical impedance of the circuit. Calculated and experimentally determined values for damping factor are compared. A formula giving the value of source resistance for critical damping is noted.

**621.395.625.3** **3118**
**Methods of Measuring Surface Induction of Magnetic Tape**—J. D. Bick. (*Jour. Soc. Mot.

*Pic. & Telev. Eng.*, vol. 62, p. 383; May, 1954.) Correction to paper abstracted in 2552 of 1953.

621.395.625.3 3119

**Bibliography of Magnetic Recording 1900–1953**—A. Jorysz. (*Tele-Tech*, vol. 13, pp. 54–56, 112; July, 1954.)

## ANTENNAS AND TRANSMISSION LINES

621.372.2 3120

**Theory of Composite Guides: Stratified Guides for Surface Waves**—A. E. Karbowiak. (*Proc. IEE*, part III, vol. 101, pp. 238–242; July, 1954.) The propagation of the plane surface wave over a guide consisting of two layers of different media covering a third semi-infinite medium is investigated and expressions are derived for the decay coefficient and the surface impedance. Four special cases are considered: (a) the third medium a perfect conductor, (b) a conductor coated with several layers of different dielectrics, (c) electroplated surfaces, and (d) single-wire transmission lines.

621.372.2 3121

**Loss Measurements of Surface-Wave Transmission Lines**—E. H. Scheibe, B. G. King and D. L. Van Zeeland. (*Jour. Appl. Phys.*, vol. 25, pp. 790–797; June, 1954.) Several methods of measurement are discussed; one involving the $Q$ of a resonator formed by short-circuiting both ends of a length of line was found best. Measurements were made on ten dielectric-coated wires, at 9.365 kmc; the losses ranged from about 3 db/100 feet for thin coatings to about 11.5 db/100 feet for thick coatings. Results are tabulated and compared with values derived from Goubau's analysis.

621.372.2 3122

**Surface Waves Propagated along a Single Cylindrical Conductor**—M. D. Karasev and V. A. Apanasenko. (*Zh. Tekh. Fiz.*, vol. 24, pp. 662–666; April, 1954.) Experimental confirmation of Goubau's results (812 of 1951) is reported. The attenuation of the line with launching horns was $<3$ db at $10^{10}$ cps using copper conductors of radius 0.024–0.125 cm and length 150–285 cm. The horn radius could be reduced to 5 cm with negligible change of energy losses. Results of measurements of the magnetic field at radial distances up to $\sim$1.25 cm from the axis of the conductor are shown graphically. Results of similar measurements on an enamel-covered copper conductor are also shown.

621.372.2:621.315.212 3123

**Coaxial Line with Helical Inner Conductor**—W. Sichak. (Proc. I.R.E., vol. 42, pp. 1315–1319; August, 1954.) Analysis is presented for the general case. The expression $(2\pi Na)(2\pi a/\lambda)$ is found to represent a significant parameter, $N$ being the number of turns per unit length and $a$ the helix radius. The variation of propagation velocity and helix impedance with line dimensions is examined separately for cases where this parameter is (a) smaller than, and (b) greater than unity. The influence of dielectrics inside and outside the helix is discussed. From consideration of $Q$ values it is found that for frequencies below about 500 mc the volume of a line of this type is considerably less than that of a conventional coaxial-line resonator.

621.372.2:621.315.212 3124

**Transmission Formulas and Charts for Laminated Coaxial Cables**—R. A. King and S. P. Morgan. (Proc. I.R.E., vol. 42, pp. 1250–1258; August, 1954.) Metal losses in laminated cables [2908 of 1951 (Clogston)] are compared with the losses in conventional coaxial cable and the optimum proportions for the laminated cable are discussed. Dielectric losses and the effects of nonuniformities are also considered. Formulas and charts for the attenuation and bandwidth characteristics are presented and their use is illustrated by numerical examples.

621.372.2:621.315.212.011 3125

**Secondary Parameters of a Coaxial Pair at High Frequencies**—R. Cazenave. (*Cables & Trans.*, vol. 8, pp. 159–171; April, 1954.) Calculation of attenuation, phase shift, phase velocity and characteristic impedance, given permittivity and loss angle of the dielectric, is simplified at frequencies above 1 mc by using asymptotic expressions for resistance and inductance per unit length (1194 of 1952). Exact representation of the characteristic impedance by the impedance characteristic of an equivalent *RC* network is not possible at the higher frequencies.

621.372.51:621.315.212 3126

**Conical Joint**—E. G. Solov'ev. [*Radiotekhnika (Moscow)*, vol. 9, pp. 76–78; May/June, 1954.] The two coaxial connectors considered are (a) a conical conductor inside a cylindrical conductor, and (b) coaxial cylindrical conductors with conical internal surface of external conductor. The wave impedance, defined as the ratio of the pd between the conductors to the current flowing in one of them, is calculated. The real part of the expression equals in the first approximation the characteristic impedance of a coaxial line having the same dimensions as the conical junction at the given section, the reactive component depends on the geometry, the medium, and the wavelength, increasing with increasing wavelength.

621.372.8 3127

**Time Constant of a Cylindrical Electric Guide**—P. Poincelot. [*Compt. Rend. Acad. Sci. (Paris)*, vol. 238, pp. 2394–2395; June 21, 1954.] Analysis is given for a guide with a perfectly conducting metal wall, using theory developed previously (2179 of 1952). A calculation for the case of a guide of diameter 76.5 mm and length 3 km, excited by a klystron on a wavelength of 8.6 mm and operating in the $H_{01}$ mode, gives a time $>40$ mμs for the signal on arrival to grow from 0.1 to 0.9 of its steady-state value.

621.372.8 3128

**Some Results of the General Theory of Waveguides with Diaphragms**—G. N. Rapoport. [*Radiotekhnika (Moscow)*, vol. 9, pp. 79–80; May/June, 1954.] Formulas are given for the numerical evaluation of the equivalent susceptance of a single plane diaphragm with an arbitrarily shaped aperture, for the distribution of the field and dispersion of normal waves in a waveguide with diaphragms, and for the constants of the equivalent quadripole.

621.372.8:[537.562+621.318.134 3129

**Topics in Guided Wave Propagation through Gyromagnetic Media: Part 2—Transverse Magnetization and the Non-Reciprocal Helix**—H. Suhl and L. R. Walker. (*Bell Sys. Tech. Jour.*, vol. 33, pp. 939–986; July, 1954.) "Propagation through a gyromagnetic medium in a direction normal to a uniform magnetizing field is considered. Geometrical arrangements which make this propagation nonreciprocal are described. A few illustrative examples are discussed briefly. The nonreciprocal helix, of importance in traveling wavetube work, is treated at length." Part 1: 2563 of October.

621.372.8.002.2 3130

**Light-Weight Waveguides**—P. A. Akin. (*Elec. Mfg.*, vol. 53, pp. 112–117; March, 1954.) Report of U. S. Air Force investigations into the production of lightweight waveguides. Two methods were developed, one using magnesium and the other stainless-steel strip.

621.372.8.011.2 3131

**Characteristic Impedance of Rectangular Waveguides with $H_{10}$ Waves**—H. Meinke and H. W. Urbars. (*Fernmeldetech. Z.*, vol. 7, pp. 247–248; May, 1954.) The definition of the characteristic impedance is discussed.

621.396.67 3132

**Determination of a Direction of Maximum Gain and Stationary Polarization for the Monochromatic Electromagnetic Radiation at Infinity of an Arbitrary [aerial] System**—M. Bouix. [*Compt. Rend. Acad. Sci. (Paris)*, vol. 239, pp. 35–37; July 5, 1954.] A formula derived by Goudet (340 of 1948) is used to determine the condition for the gain to be maximum (i.e. the modulus of the Poynting vector to be maximum) in a given direction. There is no essential incompatibility between this condition and that for the polarization to be stationary in the same direction.

621.396.67:538.566 3133

**Electromagnetic Field of a Dipole Source above a Grounded Dielectric Slab**—Lo. (*See* 3201.)

621.396.677:621.318.134 3134

**Ferrite Rod Aerials**—W. A. Everden. (*Wireless World*, vol. 60, pp. 440–444; September, 1954.) Underlying principles are discussed and design formulas are presented for antennas based on ferroxcube rods in grade *B2*, having an initial permeability of about 200, resistivity $10^6$ Ω.cm and loss factor $90\times10^{-6}$ at 0.5 mc. The influence of coil position and type of winding is investigated.

621.396.677.3+621.396.677.71 3135

**On the Design of Arrays**—J. N. Hines, V. H. Rumsey and T. E. Tice. (Proc. I.R.E., vol. 42, pp. 1262–1267; August, 1954.) Exact design theory for antenna arrays is given which takes account of the modification of the radiation pattern of individual elements due to the presence of the other elements of the array. Results obtained for a traveling-wave slot antenna are compared with those obtained previously by the approximate method [334 of February (Hines et al.)]. Use of the exact method is particularly important when designing arrays to give very weak side lobes.

621.396.677.3 3136

**The Principle and the Design of the Yagi-Uda Antenna: Part 2**—S. Uda and Y. Mushiake. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B.* vol. 5, pp. 51–75; June, 1953.) Application of the theory given in part 1 (2314 of August) to the design of the fed element, the reflector and the director elements, illustrated by numerical examples. Design charts, tables, formulas and a nomogram are given for two- and three-element antennas.

621.396.677.3:523.7:621.396.822.029.64 3137

**Multiple-Element Interferometer for Locating Sources of Solar Noise at 4000 Mc/s**—Tanaka and Kakinuma. (*See* 3204.)

621.396.677.7 3138

**Radiation Properties of the Open End of a Rectangular Waveguide when the End Plane is inclined to the Guide Axis**—G. S. Sanyal. (*Indian Jour. Phys.*, vol. 27, pp. 465–475; September, 1953.) Radiation patterns were obtained experimentally for waveguides of internal dimensions 0.9 inch×0.4 inch, with the plane of the open end perpendicular to the *H* plane but inclined at various angles to the axis; excitation wavelengths of 3.2–3.5 cm were used. The best compromise as between small width of major lobe and low intensity of minor lobes was obtained for an inclination of about 50 degrees. Calculations based on diffraction theory give results in fair agreement with those obtained experimentally. Measurements of the vswr indicate that matching between the open end and free space is better when the inclination is greater.

621.396.677.832 3139

**Directivity Diagrams of Corner-Reflector Slot Aerials**—G. N. Kocherzhevski [*Radiotekhnika (Moscow)*, vol. 9, pp. 33–37; May/June, 1954.] Experimentally determined polar diagrams are presented for antennas of side lengths between 0.5 and 1.5 λ, heights between 1 and 1.5 λ and angles between 60 degrees and 240 degrees. The characteristics are in fair agreement with curves calculated from the formulas given.

## AUTOMATIC COMPUTERS

681.142 3140

**Applications of a High-Speed Electronic Computer to a Business-Accounting Problem**—A. St. Johnston and S. L. H. Clarke. (*Jour. Brit. IRE*, vol. 14, pp. 293–302; July, 1954.)

681.142 3141

**Digital Servomechanism controls Shaft Position**—L. T. Thomasson. (*Electronics*, vol. 27, pp. 134–139; August, 1954.) Devices for converting data from digital to analog form are discussed; two experimental systems which convert binary-digital input signals into shaft-rotation angles are described. The converter functions as a closed-loop servomechanism in which the error-sensing portion is a digital computer. Information can be indicated remotely with an accuracy within 0.1 per cent.

681.142 3142

**A One-Dimensional Fourier Analog Computer**—L. V. Azaroff. (*Rev. Sci. Instr.*, vol. 25, pp. 471–477; May, 1954.) The computer sums Fourier series having up to 30 terms, and can be used for double and triple summations by using standard trigonometric expansions.

681.142:517.9 3143

**Solution of Second-Order Differential Equations and Partial Differential Equations using a Resistance Network**—R. Servranckx. [*Rev. HF* (*Brussels*), vol. 2, no. 10, pp. 271–276; 1954.] Description of an instrument based on Liebmann's design (1954 of 1950), which has an accuracy within about 1 part in $10^3$.

681.142:519.272.1 3144

**Direct-Reading Electronic Correlator**—J. C. Pebay-Peyroula and P. Simon. (*Jour. Phys. Radium*, vol. 15, supplement to no. 5, pp. 101A–108A; May, 1954.) Paper-strip recordings of two functions are read photoelectrically, and the electrical signals thus obtained are converted into pulses which, when coincident, actuate a computer. The correlation delay time can be varied up to any value from a lower limit set by the recording speed.

681.142:621-52 3145

**Statistical Computers as applied to Industrial Control**—P. Huggins. (*Jour. Brit. IRE*, vol. 14, pp. 309–321; July, 1954.) Principles and circuit techniques are discussed; applications described include the control of the diameter of extruded plastic cable sheathing.

681.142:621.314.634 3146

**The Selenium Rectifier in Digital Computor Circuits**—A. D. Booth and A. D. Holt. (*Electronic Eng.*, vol. 26, pp. 348–355; August, 1954.) Results are reported of an investigation of the Birkbeck College computer with the object of replacing tubes by more reliable elements where possible. Measurements indicate that ¼-inch-diameter Se-disk rectifiers are suitable for use as shift diodes, buffer isolators, gating elements, coincidence-sensing units and decoding-matrix elements, in computers where the frequency of operation does not exceed 30 kc.

681.142:621.316.313 3147

**A New A.C. Network Analyser for the Solution of Problems arising in the Operation and Extension of Electrical Power Systems**—E. Fässler. (*Brown Boveri Rev.*, vol. 40, pp. 455–461; November/December, 1953.)

681.142:621.317.32 3148

**An Analogue Computing Circuit for the Evaluation of the Ratio of Two Slowly-Varying Potentials**—R. L. Gordon. (*Jour. Sci. Instr.*, vol. 31, pp. 166–169; May, 1954.) The circuit, based on the Miller integrator, is described in detail; the computed ratio is displayed as a meter deflection. The use of feedback reduces the sensitivity to valve-characteristic variations; the error is less than 1 per cent of full-scale deflection within wide input limits. Computation of reciprocals and products may be performed by means of similar circuits. Several possible applications of the device are mentioned.

681.142:621.383 3149

**The A.D.E. Photo-Electric Integrator**—J. R. Lowe. [*Nature* (*London*), vol. 173, pp. 1222–1223; June 26, 1954.] The instrument, which is in the developmental stage, is capable of evaluating surface integrals of any function over a domain with boundaries not containing poles of the function. It comprises essentially a bottom-lit light-diffusing table with a photoplate grating and photoelectric cell arranged above; the grating represents the function and an opaque mask represents the domain of integration. Integrals of a bivariate normal distribution function over a domain with irregular boundaries have been obtained.

## CIRCUITS AND CIRCUIT ELEMENTS

621.316.8.029.3:621.317.723 3150

**Charge-Carrier Device as a High Ohmic Resistance**—W. Kossel, F. Leonhard and P. Volk. (*Z. angew. Phys.*, vol. 6, pp. 213–215; May, 1954.) The principle of the two arrangements described is the movement of a conductor (a metal ball of capacitance $C_k$) to and fro at a specified frequency ($n$) in an es field between two electrodes. The effective resistance, $R$, of the circuit is $1/n\ C_k$. In the first arrangement, the ball is fitted to the periphery of an insulated disk driven by a synchronous motor; in the second, the ball is free and its movement is controlled by an electromagnet. Details are given of the performance of the system operating in an electrometer circuit, with balls of different materials. With a ball 3 mm in diameter, frequency 50 cycles/minute, and electrode spacing 4 mm, $R=2.8\times10^{12}\Omega$.

621.316.86:537.312.6 3151

**Thermistor Nomograph**—V. M. Bolis. (*Electronics*, vol. 27, p. 178; August, 1954.) Chart for finding values of thermistor resistance at given temperature. The accuracy is nearly as good as that of a slide rule.

621.318.4.042.12 3152

**Demagnetization Coefficients of High-Permeability Cores**—H. A. Rozenblat. (*Zh. Tekh. Fiz.*, vol. 24, pp. 637–661; April, 1954.) Experimental determination of the dependence of demagnetization coefficients on geometrical dimensions of solid or laminated cores of rectangular cross section and solid or hollow cylindrical cores. A semiempirical formula for calculating the demagnetization coefficient of cylindrical, rectangular cross section, and ellipsoidal cores is given and the calculated results are shown to be in good agreement with measurements.

621.318.57 3153

**An Electronic Ratchet**—H. J. Moody and G. J. B. Crawford. (*Canad. Jour. Phys.*, vol. 32, pp. 356–358; May, 1954.) When groups of nine evenly spaced pulses are applied to a decade scaler, a series of output pulses is obtained with separation increasing by one time unit for each pulse group. Application of groups of eight pulses gives separation increasing by two time units per group, while groups of eleven pulses decrease the separation by a single unit. The instrument described comprises two decade scalers and can provide a maximum separation of 98 time units for increasing intervals or 100 for decreasing intervals.

621.319.43 3154

**Component Design Trends—New Variable Capacitors extend Tuning Range**—F. Rockett. (*Electronics*, vol. 27, pp. 130–133; August, 1954.) Over 200 different types of variable capacitors in production were surveyed. An outline is given of techniques used for obtaining low minimum capacitance and high maximum capacitance, adapting for operation at uhf, miniaturizing and pressurizing.

621.319.43 3155

**A Simple Three-Terminal Micrometer Capacitor**—M. C. McGregor. (*Jour. Sci. Instr.*, vol. 31, pp. 190–191; May, 1954.) Description of a variable capacitor in which a micrometer spindle moves along the axis of a hollow cylinder which is coaxial with a cylindrical hole bored in the brass-block screen. Typical range is from 1 to 6 *pF* for a 1-inch movement of the spindle.

621.372:621.314.7 3156

**Transistor Characteristic Parameters for Weak Alternating Currents**—H. Henker. (*Arch. elekt. Übertragung*, vol. 8, pp. 213–216; May, 1954.) A method of representation is proposed, using an impedance matrix, which is completely symmetrical for all six transistor connections. Formulas derived for input impedance, current gain, etc. have the same form for all the six circuits. The method requires a new definition of the currents and voltages, but affords the possibility of extension to multielectrode systems. The setting-up of matrixes for complex arrangements of resistors and transistors is illustrated.

621.372.2 3157

**Multilayer Distributed Constant Delay Lines**—W. J. Carley. (*Tele-Tech*, vol. 13, pp. 74–76, 102; May, 1954.) See 2257 of 1953 (Carley & Seymour).

621.372.5 3158

**Synthesis of Passive Networks with *n* Pairs of Terminals specified by their Scattering Matrices**—Y. Oono and K. Yasuura. (*Ann. Télécommun.*, vol. 9, pp. 73–80, 109–115 and 133–140; March–May, 1954.) The method described gives results different from those of Belevitch (1547 of 1952 and back references). Equivalent networks are represented by means of a uniquely defined "regular" network matrix. Necessary and sufficient conditions for minimum phase shift are specified in terms of matrix theory, and the minimum number of elements, excepting ideal transformers, required in equivalent networks is determined. Relevant matrix theory is dealt with in an appendix. The method is extended to networks violating the reciprocity principle.

621.372.5 3159

**Reciprocity Relations in Active 3-Terminal Elements**—J. Shekel. (PROC. I.R.E., vol. 42, pp. 1268–1270; August, 1954.) It is shown by matrix analysis that under small-signal conditions an active element such as a tube or transistor can be represented by an equivalent circuit comprising a triangle of resistances and a three-terminal gyrator. The active element is stable if one, and only one, of the resistances is negative. It is shown that the property of nonreciprocity is essential for an active three-terminal element to be stable.

621.372.5 3160

**Notes on the Gyrator Problem**—W. Doebke. (*Arch. elekt. Übertragung*, vol. 8, pp. 197–200; May, 1954.) The impedance transformation properties indicated by Tellegen (980 of 1949) as characteristic of the gyrator can also exist in ordinary quadripoles. The peculiar nature of the gyrator is indicated by the sign of the output current. Different conventions used in representing quadripole currents and voltages are discussed. It is proposed that the equations should be written in a way that takes into account the terminating impedances and the internal impedance of the source.

621.372.5:538.652:546.289 3161

**Solution of the Field Problem of the Germanium Gyrator**—R. F. Wick. (*Jour. Appl. Phys.*, vol. 25, pp. 741–756; June, 1954.) Analysis is presented for the Hall-effect gyrator described by Wick et al. (1930 of 1953) treated as a two-dimensional boundary-value problem and assuming that only one type of carrier is involved and that there is no surface recombination. The efficiency is calculated as a function of electrode size, shape of boundary, and magnetic field strength. Some of the results have been checked experimentally with fields up to 22,000 gauss. The calculations have been carried out for even higher fields, and may be useful for studying materials with higher mobilities, such as InSb.

621.372.5:621.3.012.1 3162

**Impedance Transformation by Four-Terminal Networks**—S. Fedida. (*Wireless Eng.*, vol. 31, pp. 204–214 and 239–249; August and September, 1954.) The geometrical interpretation of impedance transformations is considered in relation to the use of impedance charts and improved methods of impedance measurement.

621.372.5:621.3.016.35 3163

**Intrinsic Stability: Conditions for Equivalence between a Quadripole including Active Elements and a Passive Quadripole**—J. M. Moulon. (*Cables & Trans.*, vol. 8, pp. 153–158; April, 1954.) There are two necessary conditions: (a) image impedances must be passive; (b) image attenuation must exceed the value of a certain function of the phase angle of the image impedance and the image phase-shift coefficient; in certain important cases this second condition reduces to a simple mathematical form.

621.372.5:621.376.3:621.3.018.78 3164

**Distortion of a Frequency-Modulated Wave passing through a Mismatched Quadripole**—L. J. Libois. (*Cables & Trans.*, vol. 8, pp. 195 200; April, 1954.) Analysis is based on the transfer coefficient of the network and a formula is derived for nonlinear distortion in the general case. From this the percentage of odd and even harmonics generated and the upper limit of the distortion factor can be determined. Application of the formula in the case of transmission lines is illustrated.

621.372.5.015.3:621.376.3 3165

**Transient Response in F.M.**—I. Gumowski. (Proc. I.R.E., vol. 42, p. 1267; August, 1954.) Correction to paper abstracted in 2337 of September.

621.372.54 3166

**Response of a Low-Pass or Band-Pass Filter to a Voltage whose Instantaneous Frequency varies Linearly as a Function of Time**—P. Poincelot. [*Compt. Rend. Acad. Sci.* (*Paris*), vol. 239, pp. 245–247; July 19, 1954.] Analysis is given based on a Fourier-integral representation of the input voltage. A formula derived for the output voltage is shown to be applicable in the case of a panoramic receiver in which the frequency is varied by 200 kc in $10^{-2}$ seconds.

621.372.54 3167

**Conformal Mapping for Filter Transfer Function Synthesis**—G. L. Matthaei. (Proc. I.R.E., vol. 42, p. 1319; August, 1954.) Correction to paper abstracted in 357 of March.

621.372.54:621.396.822 3168

**On the Filter Problem of the Power-Spectrum Analyzer**—S. S. L. Chang. (Proc. I.R.E., vol. 42, pp. 1278–1282; August, 1954.) In an analyser for determining the power spectrum of random noise, a signal derived by repeating a finite sample of the noise record is heterodyned with another signal whose frequency is swept over the whole spectrum, and the resultant is passed through a narrow filter and then detected. An investigation is made of the optimum filter response for minimizing the intrinsic error associated with the finite size of the sample; the lowest probable error for various types of filter is tabulated. The rate of the frequency sweep must be small compared to the half-bandwidth squared for the filter response to remain substantially the same as its steady-state response.

621.373.421 3169

**The Bridge-Stabilized Transformerless Oscillator with Complex Amplification Factor**—W. Ziegler. (*Frequenz*, vol. 8, pp. 144–159; May, 1954.) Oscillators of the type described by Zaiser (425 of 1944), with *RC* frequency-determining circuits, are discussed. The effect of complex transfer factor is investigated, and the conditions are determined under which oscillations at unwanted frequencies are suppressed without impairing the frequency stability of the wanted oscillation.

621.373.521.11 3170

**Frequency Stable *LC* Oscillators**—J. K. Clapp. (Proc. I.R.E., vol. 42, pp. 1295–1300; August, 1954.) Literature on the subject is reviewed and attention is drawn to the chronological order of various publications. Simple theory is presented for the conditions governing oscillation and frequency stability.

621.373.43 3171

**The Type-6218 Beam-Deflection Tubes as a Complex Pulse Generator**—K. Enslein. (*Rev. Sci. Instr.*, vol. 25, pp. 355–358; April, 1954.) Type-6218 is the U.S.A. designation for the Type-E80T tube (2843 of 1953). Circuits for producing single, double, or multiple pulses with very short rise time are described.

621.373.43 3172

**Contribution to the Mathematical Description of Relaxation Oscillations**—P. Jean. (*Jour. Phys. Radium*, vol. 14, p. 36S; October, 1953.) Differences and similarities between oscillations of relaxation and of van der Pol type are discussed. Relaxation oscillations can be represented by the van der Pol equation if the self-inductance term in the latter is neglected and a suitable transformation is made.

621.373.44 3173

**20-Kilovolt Delta-Function Generator**—H. G. Heard. (*Rev. Sci. Instr.*, vol. 25, pp. 454–458; May, 1954.) A 20-kv pulse is generated in a circuit comprising two series-connected hydrogen thyratrons arranged to constitute the inner conductor of a 50-Ω coaxial line. It is passed through 40 feet of RG-8U cable to a delta-function generator which includes a pulse-sharpening gap and differentiating stub. This generator reduces the pulse rise time to $<0.6$ mμs and the pulse width to 2.5 mμs. Pulses of either polarity may be obtained.

621.373.52.029.3 3174

**Analysis of Junction-Transistor Audio-Oscillator Circuits**—J. B. Oakes. (Proc. I.R.E., vol. 42, pp. 1235–1238; August, 1954.)

621.374.34 3175

**A Clipper with Automatic Mark-Space Ratio Control**—A. B. Johnson. (*Electronic Eng.*, vol. 26, pp. 364–365; August, 1954.) A rectangular wave with mark/space ratio independent of the amplitude and harmonic content of the input wave is produced by controlling the bias level of the first clipping stage by means of a special feedback circuit incorporating a mark /space ratio discriminator.

621.375.221.2 3176

**Distributed Amplifiers: some New Methods for Controlling Gain/Frequency and Transient Responses of Amplifiers having Moderate Bandwidths**—H. G. Bassett and L. C. Kelly. (*Proc. IEE*, part III, vol. 101, p. 237; July, 1954.) Discussion on 1359 of June.

621.375.223 3177

**High-Frequency Compensation of *RC* Amplifiers**—F. A. Muller. (Proc. I.R.E., vol. 42, pp. 1271–1276; August, 1954.) A discussion with special reference to transient response. Optimum values are tabulated for the circuit parameters for some typical circuits and compensating arrangements. In a multistage amplifier simply compensated by means of a coil in the anode leads, the rise time can be reduced to 55–60 per cent of the uncompensated value if the time constants of the stages are equal, and to 45 per cent if the time constants are staggered.

621.375.23 3178

**Design of the Duplex Feedback Amplifier**—J. Oizumi. (*Sci. Rep. Res. Inst. Tohoku Univ.*, *Ser. B*, vol. 5, pp. 1–50, 115–141 and 215–249; June, 1953–March, 1954.) A comprehensive discussion illustrated by a detailed account of the design of carrier-telephone repeater amplifiers.

621.375.9:537.312.8 3179

**The Galvanomagnetic Amplifier**—H. J. Thuy. (*Arch. elekt. Übertragung*, vol. 8, pp. 217–222 and 269–278; May and June 1954.) Discussion of theoretical and practical aspects of an amplifier whose operation depends on the magnetic control of electrical resistance (Gauss effect). Such an arrangement is less noisy than magnetic or dielectric amplifiers at low temperature. Among metals, bismuth exhibits the greatest sensitivity to this effect. By using an appropriate material such as InSb the principle can also be applied to amplifiers for use at room temperature. The theoretically possible gain is 30–40 db at 90 degrees K and 50–60 db at 20 degrees K; corresponding values which have been obtained with experimental units are about 13 and 31 db.

621.376.22+621.376.32]:621.385.029.64 3180

**723 A/B Reflex Klystron Performance**—G. Zito. (*Z. angew. Phys.*, vol. 5, pp. 252–260; May 15, 1954. In English.) From a series of measurements made while varying the anode and reflector voltages simultaneously, constant-frequency and constant-power $V_a/V_r$ curves can be constructed. Typical curves for three modes of operation at 9.369 kmc are shown. With the aid of these curves extremely pure amplitude or frequency modulation can be achieved, by varying $V_a$ and $V_r$ simultaneously so that the ratio of their variations is constant; the change from AM to FM may be effected simply by altering the ratio. The maximum frequency shift with AM was about ±1.3 mc. With FM, a frequency swing of 40 mc was obtained with constant power output of 13 mw. An important application of the systems described is the modulation of signal generators for measurement purposes.

621.376.23 3181

**A Broadband, Low-Level, Error-Voltage Detector**—M. L. Kuder. (*Rev. Sci. Instr.*, vol. 25, pp. 464–468; May, 1954.) The unbalance of a carrier-frequency voltage in a bridge circuit having two inductive and two Ge-diode arms is used for detecting small dc or ac error signals. Sensitivity down to 1 mv and response within 1 μs are provided by the instrument, which is relatively free from zero drift. Application to high-speed multichannel sampling and to servo systems is discussed.

621.376.232:621.385.5 3182

**Direct-Coupled Transitron**—F. A. Milne and E. J. Miller. (*Wireless Eng.*, vol. 31, pp. 234–239; September, 1954.) Transitron arrangements are discussed in which the screen grid and suppressor grid of the pentode are connected via a resistance network. Various practical applications are possible as a result of a discontinuity in the $I_a/V_g$ characteristic. Circuits for (a) detection of direct-voltage changes, e.g. amplifier-gain alarm, (b) detection of alternating-voltage changes, e.g. peak suppressors, and (c) rectification of voltages exceeding a given level are considered. Careful design is necessary to overcome variations between individual tubes, but a very sharp trigger action can be produced. The high sensitivity makes circuit economics possible.

621.376.32:538.614 3183
**Microwave Single-Sideband Modulator using Ferrites**—J. Cacheris. (Proc. I.R.E., vol. 42, pp. 1242–1247; August, 1954.) The modulator uses a ferrite rod inserted in a waveguide section, and subjected to a rotating transverse magnetic field, as a 180 degree phase shifter. A transmission type and a reflection type are described; both are designed to shift the frequency of an $X$-band signal by 20 kc.

621.318.2+621.318.4 3184
**Small Transformers and Inductors (Book Review)**—K. A. Macfadyen. Publishers: Chapman & Hall, London, Eng., 1953, 237 pp., 37s. 6d. (*Proc. Phys. Soc.*, vol. 67, pp. 445–446; May 1, 1954.) "There has long been the need for a book which treats the design of transformers for use at both power and communication frequencies on the basis of a common, systematic theory, and which so closely relates the design process to fundamental theory as to enable the non-specialist successfully to undertake the design of transformers for widely differing applications. The author has fulfilled this need most admirably."

## GENERAL PHYSICS

530.145 3185
**On the Nature of Waves**—F. Bopp. (*Z. angew. Phys.*, vol. 6, pp. 235–238; May, 1954.) Critical discussion of classical theory indicating how an interpretation of the quantum theory can resolve the incompatibility of wave and particle concepts.

536.49:621.319.4 3186
**Theory of Thermodielectric Effect**—B. Gross. (*Phys. Rev.*, vol. 94, pp. 1545–1551; June 15, 1954.) "A theory is put forth to explain the electrical effects which accompany phase changes occurring in dielectrics and aqueous solutions. Ionic movement in the interface is treated as a transition between energy levels separated by potential barriers. The height of the barriers and the value of the energy levels are supposed to be different for positive and negative ions. Such a model results in a net current flow across the solid-liquid interface. When the interface moves during a phase change of the system, the excess electric charges thus produced constitute space charges in the solid and surface charges in the liquid." See also 2621 of October (Dias Tavares) and back references.

537.122 3187
**A New Classical Theory of Electrons: Part 3**—P. A. M. Dirac. (*Proc. Roy. Soc. A*, vol. 223, pp. 438–445; May 20, 1954.) The theory previously proposed (1574 and 3059 of 1952) is applied to a system comprising several interpenetrating streams of electricity moving in accordance with the equations of Maxwell and Lorentz. An action principle is set up, and the equations of motion are put in the Hamiltonian form. The Hamiltonian has some similarity to that for point-charge electrons but there is some discrepancy.

537.122 3188
**A Theory of the Electron**—H. T. Flint and E. M. Williamson. (*Nuovo Cim.*, vol. 11, pp. 568–569; May 1, 1954. In English.) Further development of the theory proposed previously (2066 of August).

537.212 3189
**The Electric Field of Conductors arranged parallel to Conducting Planes intersecting at a Given Angle**—H. Rösch. (*Arch. elekt. Übertragung*, vol 8, pp. 229–237; May, 1954.) Convenient formulas are obtained by considering the field as the resultant of those due to the multiple reflections of the conductor in the intersecting planes. These formulas are shown to agree with those derived by the method of conformal transformation.

537.3 3190
**Anomalous Electron Scattering in Metals**—D. K. C. MacDonald and W. B. Pearson. (*Phil. Mag.*, vol. 45, pp. 491–496; May, 1954.) "A semi-theoretical equation was proposed previously to account qualitatively for the thermoelectric power of metals and alloys, particularly at low temperatures. The consequences of this equation are now examined quantitatively in relation to experimental data on alloys of copper."

537.52 3191
**Some Measurements of the Relative Dielectric Strength of Gases**—N. R. McCormick and J. D. Craggs. (*Brit. Jour. Appl. Phys.*, vol. 5, pp. 171–173; May, 1954.) Electronegative gases including $SF_6$ and $Cl_2$ were studied by measuring the breakdown voltages of sphere gaps with spacings of a few millimeters. Results are tabulated and discussed, taking nitrogen as comparison standard.

537.525.6 3192
**Electron Energy Distributions in Stationary Discharges**—I. B. Bernstein and T. Holstein. (*Phys. Rev.*, vol. 94, pp. 1475–1482; June 15, 1954.) Extension of previous analysis [1407 of 1947 (Holstein)] to the case of a stationary discharge in a dc space-charge field. The effect of the space charge is to increase the proportion of high-energy electrons. This results in a higher ionization rate, but the effect is not large enough to account for low maintenance potentials observed in positive columns and in microwave discharges in inert gases.

537.533:621.38.032.212 3193
**Electron Emission from Cold Metal Surfaces at Medium Field Strengths ($\sim 10^4$ V/cm)**—K. Kerner and H. Raether. (*Z. angew. Phys.*, vol. 6, pp. 212–213; May, 1954.) Measurements were made of the field emission of an Fe cathode at pressures $<10^{-5}$ Torr. The emission/field-strength characteristic depends largely on the pretreatment of the cathode material. Applying Schottky's equation a value of 1–2 ev is obtained for the work function.

537.533.8:546.46-31 3194
**Energy and Temperature Dependence of the Secondary Emission of MgO**—A. J. Dekker. (*Phys. Rev.*, vol. 94, pp. 1179–1182; June 1, 1954.) The results reported by Johnson and McKay (114 of February) are interpreted quantitatively on the basis of a simple one-dimensional model.

537.56 3195
**Collisional Effects and the Conduction Current in an Ionized Gas**—A. A. Ware. (*Phil. Mag.*, vol. 45, pp. 547–549; May, 1954.) A note on the approximate expression derived by Westfold (115 of February) for the collision term in the current transport equation for a binary ionized gas in a strong magnetic field.

537.56:538.63 3196
**Maxwellian Approximation to the General Magneto-ionic Theory of Plasmas with an External Electric and Magnetic Field**—R. Jancel and T. Kahan. (*Jour. Phys. Radium*, vol. 15, pp. 382–383; May, 1954.) Analysis is presented to show that a Maxwellian distribution of electron velocities occurs as a particular case in the theory developed previously (2364 of September and back references).

538.248 3197
**Variation of Diffusion-After-Effect Field with Induction**—P. Brissonneau. [*Compt. Rend. Acad. Sci.* (*Paris*), vol. 239, pp. 346–349; July 26, 1954.] As a consequence of the different behaviour of 90 degree and 180 degree walls, the curve representing the variation of diffusion-after-effect field with induction exhibits two horizontal regions; this is confirmed experimentally.

538.3 3198
**General Formulae for the Theory of Polarized Media**—É. Durand. [*Compt. Rend. Acad. Sci.* (*Paris*), vol. 238, pp. 2504–2506; June 28, 1954.] The classical equations of electromagnetic theory are generalized and are all derived from two fundamental formulas by a chain of definitions and identities.

538.3 3199
**Reaction Concept in Electromagnetic Theory**—V. H. Rumsey. (*Phys. Rev.*, vol. 94, pp. 1483–1491; June 15, 1954.) A mathematical definition is given of a physically observable quantity termed the "reaction" which is a measure of the force exerted by one em source on another. The concept is used to obtain expressions for scattering coefficients, transmission coefficients and aperture impedances. The advantage of using this concept rather than the variational approach is illustrated by treating the problem of scattering by a dielectric body.

538.3 3200
**Some Consequences of the Theory of Action at a Distance in Classical Electrodynamics**—P. Braffort, M. Spighel and C. Tzara. [*Compt. Rend. Acad. Sci.* (*Paris*), vol. 239, pp. 157–160; July 12, 1954.] The energy taken by a free charge and by a harmonic oscillator is calculated on the absorber theory.

538.566:621.396.67 3201
**Electromagnetic Field of a Dipole Source above a Grounded Dielectric Slab**—Y. T. Lo. (*Jour. Appl. Phys.*, vol. 25, pp. 733–740; June, 1954.) A theoretical investigation, using the method of integral transforms. Solutions in integral form are evaluated asymptotically by the saddle-point method; the distant field is found to be the resultant of a spherical space wave and a cylindrical surface wave. Calculated radiation patterns for some particular cases, with and without the dielectric slab, are presented.

538.614:[546.562.26+546.712.26 3202
**Faraday Effect at Centimetre Wavelengths**—N. Neprimerov. (*Zh. Eksp. Teor. Fiz.*, vol. 26, p. 511; April, 1954.) A brief note on Faraday-effect measurements at 3.18 cm λ at field strengths up to 5,000 oersted, using a 12-pole symmetrical waveguide system (not described). Results of measurements on $CuSO_4 \cdot 5H_2O$ and $MnSO_4$ are presented graphically.

538.691 3203
**On the Nature of the Transcendental Curves Associated with the Relativistic Trajectories of Charged Particles**—L. Gold. (*Jour. Appl. Phys.*, vol. 25, pp. 691–697; June, 1954.) Analysis applicable to particles with moderate relativistic velocities, at which radiation loss is negligible. The equations of the trajectory are formulated for the general case of particles injected with arbitrary velocity into crossed electric and magnetic fields. The case of zero injection velocity is calculated explicitly. *See* also 3401 below.

## GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.7:621.396.822.029.64:621.396.677.3 3204
**Multiple-Element Interferometer for Locating Sources of Solar Noise at 4000 Mc/s**—H. Tanaka and T. Kakinuma. (*Jour. Phys. Soc. Japan*, vol. 9, pp. 364–368; May/June, 1954.) The interferometer uses five antennas,

each with a paraboloidal reflector of diameter 1.5 m, arranged at intervals of 6 m. The distribution of brightness observed at 4 kmc over the quiet sun is consistent with the conclusions that (a) the diameter of the rf disk is about 6 per cent greater than that of the optical disk, and (b) the outer ring is about 2.5 times brighter than the optical disk of uniform temperature about $1.9\times10^4$ degrees K.

523.85:621.396.822 3205

**A Method for the Measurement of the Distance of Radio Stars**—D. R. W. Williams and R. D. Davies. [*Nature* (*London*), vol. 173, pp. 1182–1183; June 19, 1954.] The method described depends on the absorption of the radiation from the radio stars by interstellar hydrogen at a frequency of about 1.42 kmc. Preliminary results are given for the two intense sources in Cygnus and Cassiopeia; the distance of the former is 9,500 parsecs, that of the latter is probably between 500 and 2,500 parsecs. The uncertainty will be reduced when more accurate measurements are made of the absorption spectrum.

523.852.2:621.396.822]:523.165 3206

**On the Nature of the Discrete Radio Sources**—R. Q. Twiss. (*Phil. Mag.*, vol. 45, p. 549; May, 1954.) Correction to paper abstracted in 2380 of September.

550.385:523.746 3207

**The Distribution of Great and Small Geomagnetic Storms in the Sunspot Cycle**—H. W. Newton and A. S. Milsom. (*Jour. Geophys. Res.*, vol. 59, pp. 203–214; June, 1954.) A statistical analysis of the occurrence of (a) great geomagnetic storms, (b) small storms with sudden commencements, and (c) small storms without sudden commencements, during the last seven sunspot cycles. Distribution curves for (a) and (b) agree closely with the average sunspot curve. For (c) the curve has no pronounced peak at sunspot maximum but reaches a high level two years later; these post-maximum storms, which are associated particularly with ionospheric disturbances, often show a 27-day recurrence which is not observed with the (b) and (c) types.

551.510.535 3208

**The Aeronomic Problem of Oxygen Dissociation**—M. Nicolet. (*Jour. Atmos. Terr. Phys.*, vol. 5, pp. 132–140; July, 1954.) The vertical distribution of $O_2$ above 100 km as determined from rocket data is discussed in terms of diffusion and mixing processes.

551.510.535 3209

**Group Height Calculations in the Presence of the Earth's Magnetic Field**—J. M. Kelso. (*Jour. Atmos. Terr. Phys.*, vol. 5, pp. 117–131; July, 1954.) A method of obtaining a theoretical $h'f$ curve avoiding direct numerical integration is described. It is based on integral formulas involving the derivative of height with respect to electron density and obtained as special cases of the Gauss-Christoffel quadrature formula (409 of 1953 and 2088 of August). Application to (a) linear, (b) parabolic, (c) cosine, and (d) arc-cosine distribution is illustrated and results are compared with exact calculations [1405 and 2009 of 1952 (Shinn and Whale) and 1414 of June (Shinn)]. A different method is described for the case of layer penetration.

551.510.535 3210

**The Vertical Distribution of Electrical Conductivity in the Upper Atmosphere**—H. Maeda. (*Jour. Geomag. Geoelect.*, vol. 5, pp. 94–104; November, 1953.) Data obtained from rocket measurements are used to determine the vertical distribution of conductivity and its height-integrated values for the *D*, *E* and *F* regions. The greatest conductivity value is found for the *E* layer around 100 km, hence this region is probably the seat of the electrical currents producing diurnal magnetic variations.

551.510.535 3211

**On the Law of the Variation of E-Region Maximum with the Zenith Distance of the Sun**—A. K. Saha. (*Indian Jour. Phys.*, vol. 27, pp. 431–438; September, 1953.) Analysis of $f_0E$ records obtained at Calcutta for the years 1949–1952 indicates that the value of $n$ in Chapman's formula $f_0E=f_s(\cos\chi)^n$ varies between 0.15 and 0.50. The subsolar frequency undergoes similar variations. A seasonal component of variation was most marked in 1950 and 1951, and the mean trend of the variations follows the sunspot cycle. The departures from the Chapman law are attributed to changes in the height distribution of $O_2$ in the transition region.

551.510.535 3212

**The Sporadic-E Layer at Kodaikanal**—S. Rangarajan. (*Jour. Geophys. Res.*, vol. 59, pp. 239–246; June, 1954.) Examination of ionospheric records shows that an $E_s$ layer is almost always present during the day. Two main types are distinguished: (a) a patchy type giving well spread echoes; this occurs more regularly and frequently, has a marked diurnal variation, and resembles the constant-height type observed at Brisbane by McNicol and Gipps (1899 of 1951); (b) a blanketing type occurring mostly during the afternoon. Neither meteoric nor thunderstorm activity greatly influences the formation of either type. No correlation is observed between $E_s$ and the geomagnetic field.

551.510.535 3213

**Spread F over Hawaii**—G. Reber. (*Jour. Geophys. Res.*, vol. 59, pp. 257–265; June, 1954.) Analysis of records for the period 1944–1953, showing diffuse and irregular echoes from the *F* region, indicates a much greater frequency of occurrence of spread *F* at sunspot minimum than at sunspot maximum, this difference being most pronounced in winter. A marked latitude and a less marked longitude effect are exhibited.

551.510.535:523.854:621.396.822 3214

**F-Scatter at Huancayo, Peru, and Relation to Radio-Star Scintillations**—H. W. Wells. (*Jour. Geophys. Res.*, vol. 59, pp. 273–277; June, 1954.) Analysis of $h'f$ records for the period 1938–1945 reveals marked diurnal, seasonal and annual characteristics of *F*-region scatter. This effect occurs most frequently in the period four hours before to four hours after midnight and is most prevalent during local summer. Occurrence frequency was least during 1941–1942, increasing by a factor of 3–4 by 1945. Diurnal variations correspond closely to reported characteristics of radio-star scintillations; annual and seasonal trends are not in simple agreement.

551.510.535:537.562 3215

**The Connection between Lunar Height Changes and Lunar Currents in the E Layer**—M. H. Johnson. (*Jour. Geophys. Res.*, vol. 59, pp. 247–251; June, 1954.) Height changes produced by vertical electronic diffusion in the presence of negative ions are considered. Application of the results to the *E* layer confirms the validity of previous qualitative conclusions (385 of 1953).

551.510.535:551.55 3216

**The Analysis of Fading Records from Spaced Receivers**—J. A. Ratcliffe. (*Jour. Atmos. Terr. Phys.*, vol. 5, pp. 173–181; July, 1954.) Fading records obtained in investigating ionospheric winds by the spaced-receiver method described by Mitra (96 of 1950) and Phillips (1916 of 1952) are discussed. Considerable variability in the records is to be expected even if the wind is constant in both direction and magnitude. Two particular one-hour records for vertical-incidence reflection from the *E* layer are analysed. One is consistent with constant-wind conditions, the other requires more detailed analysis.

551.510.535:551.55 3217

**The Determination of the Velocity of Winds from Spaced Fading Experiments**—G. Newstead. (*Jour. Atmos. Terr. Phys.*, vol. 5, pp. 182–185; July, 1954.) More detailed analysis referred to in 3216 above. If some assumption is made about the distribution of signal amplitude over the ground, the statistics of wind variation can be deduced.

551.510.535:551.55:523.5:621.396.96 3218

**Systematic Wind Measurements at Altitudes of 80–100 km using Radio Echoes from Meteor Trails**—J. S. Greenhow. (*Phil. Mag.*, vol. 45, pp. 471–490; May, 1954.) Wind drifts of ionized meteor trails were measured using a coherent-pulse doppler technique at a frequency of 36.3 mc. Average wind speeds and directions were obtained over hourly intervals; results for September and October, 1953 show semidiurnal and diurnal wind components corresponding to a clockwise rotation of the wind vector. The amplitudes and phases of these components are variable. A prevailing wind was also found, towards the east in September and towards the west in October. There is a positive wind velocity gradient of $\sim$2.7 m/second$^{-1}$ km$^{-1}$ between 78 and 98 km height. Large irregularities in the wind were noted. Typical records are shown and the equipment is described.

551.510.535:621.3.087.4 3219

**An Apparatus for the Detection of Weak Ionospheric Echoes**—S. Gnanalingam. (*Proc. IEE.*, part III, vol. 101, pp. 243–248; July, 1954.) FM apparatus is described, in which the principle of coherent integration is applied in the receiver. With transmitted power of 250 w and filter bandwidth of 1 cps, signals are detected with attenuation of up to 10 nepers.

551.510.535:621.396.11 3220

**Ionospheric Absorption Measurements during a Sunspot Cycle**—E. Appleton and W. R. Piggett. (*Jour. Atmos. Terr. Phys.*, vol. 5, pp. 141–172; July, 1954.) Detailed discussion of the results of measurements referred to in 1679 of 1953 (Piggott). Variation of atmospheric absorption $|\log\rho|$ with frequency $f$, where $\rho$ is the effective ionospheric reflection coefficient, is accounted for by magnet-ionic theory provided that $\nu^2 \ll (f+f_L)^2$, where $\nu$ is the electron collision frequency and $f_L$ is the gyrofrequency corresponding to the vertical component of the geomagnetic field. Examination of diurnal variations shows the average value of $n$ in the relation $|\log\rho| \propto (\cos\chi)^n$, where $\chi$ is the solar zenith distance, to be 0.75 against the value 1.5 given by simple theory; possible explanations of this are considered. Excessive absorption on certain groups of days during the months November-February is directly correlated with the occurrence of sporadic reflecting strata below *E*-layer height. Noon measurements over 18 years show a general correlation of $|\log\rho|$ with sunspot number $R$, more pronounced in summer than in winter. General conclusions drawn are that the normal absorbing stratum is located in the *D* region, and sudden disturbances associated with solar flares are probably due to increased ionization in this layer.

551.594.5 3221

**Magnetic Disturbances, Sporadic E, and Radio Echoes associated with the Aurora**—J. H. Meek and A. G. McNamara. (*Canad. Jour. Phys.*, vol. 32, pp. 326–329; May, 1954.) Data obtained from simultaneous observations of visible aurora, the earth's magnetic-field variations, vertical- and oblique-propagation radio echoes, and vhf radar echoes, are examined. Long-range hf and vhf echoes cannot in general be correlated. Reflections in both frequency ranges have coincided with the appearance of low-level auroral arcs, which are associated with magnetic bays.

551.594.5:621.396.11 3222

**Radio Echoes during Aurora**—A. G. McNamara and B. W. Currie. (*Jour. Geophys. Res.*, vol. 59, pp. 279–285; June, 1954.) Saskatoon data for 56 and 106 mc [3308 of 1953 (Currie et al.)] are reassessed. Two antennas placed at heights giving maximum resolution between echoes corresponding to first- and second-lobe radiation were used to determine whether echoes on 56 mc were due to ground scatter reflected from the lower ionosphere [2976 of 1953 (Harang and Landmark)]. Results show that practically all echoes were due to direct reflection from auroras.

551.594.5:621.396.11.029.55 3223

**Long-Range Radio Echoes from Auroral Ionization**—A. M. Peterson and R. L. Leadabrand. (*Jour. Geophys. Res.*, vol. 59, pp. 306–309; June, 1954.) Echoes believed to be from auroral ionization are consistently observed on using pulse signals frequencies 6.4, 12.9 and 17.3 mc, at the relatively low latitude of Stanford, California. Two types of echo are distinguished: discrete, of very large amplitude; and diffuse, of much smaller amplitude. Echo data show a marked correlation with visual auroras and with magnetic activity, and also indicate that reflections occur at regions well above the *E* layer.

551.594.5:621.396.11.029.55 3224

**The Location of the Auroral Absorption Zone**—V. Agy. (*Jour. Geophys. Res.*, vol. 59, pp. 267–272; June, 1954.) "A study of data from a chain of radio-wave field-strength recording stations along the 90th meridian suggests that the 'auroral absorption zone' coincides with the zone of maximum frequency of occurrence of visible aurora." The significance of the results for radio communications across the zone is discussed.

## LOCATION AND AIDS TO NAVIGATION

534.88:534.321.9:621.396.96 3225

**A Method for Ultrasonic SONAR of Plan-Position-Indication**—Y. Kikuchi. (*Sci. Rep. Res. Inst. Teheku Univ., Ser. B*, vol. 5, pp. 77–86; June, 1953.) PPI sonar equipment consists basically of several narrow-beam ultrasonic transducers spaced uniformly in a ring rotating very slowly, and switched rapidly between "send" and "receive" positions. The received pulses are used to modulate the brightness of the cr tube beam tracing out a spiral. In the experimental equipment described, the six transducers operated at a frequency of 50 kc and had a beam width of 7 degrees each. A useful range of 200 m to several kilometers is expected for operations at sea. A PPI photograph is reproduced.

621.396.93:551.594.6 3226

**New Design of Radio Direction Finder for Locating Thunderstorms**—F. Horner. (*Met. Mag.*, vol. 83, pp. 137–138; May, 1954.) Description of the main features of a twin-channel crdf instrument operating at frequencies of about 10 kc and suitable for mobile and tropical use. Its performance is similar to that of earlier designs, but simplification has been achieved by restricting the frequency range and using straight receivers. An automatic selector is incorporated for co-ordinating observations from several stations.

621.396.933 3227

**Measurement of Ships' Speeds by means of the Raydist Range Measuring Equipment**—(*Tijdschr. ned. Radiogenoot*, vol. 19, pp. 147–152; May, 1954.) An account of the method which was used for the first time on the S.S. *United States* in 1952.

621.396.96:621.374 3228

**False Echoes in Line-Type Radar Pulsers**—R. Lee. (Proc. I.R.E., vol. 42, pp. 1288–1295; August, 1954.) The operation of the dc resonant charging pulser is discussed and an explanation is given of the mechanism of the backswing which causes oscillation in the magnetron after the main pulse and thus gives rise to false echoes. Equations and curves are derived for predicting the presence or absence of echoes in a given pulser. The case of a pulser giving 4-$\mu$s pulses is treated as an example.

## MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.12 3229

**A Thermistor McLeod Gauge for a Pressure Range 1–$10^{-7}$ mm of Mercury**—R. S. Bradley. (*Jour. Sci. Instr.*, vol. 31, pp. 129–130; April, 1954.)

535.215:546.48-31:537.311.33 3230

**Optical Absorption Constant of Cadmium Oxide**—J. Stuke. (*Z. Phys.*, vol. 137, pp. 401–415; May 8, 1954.) The position, at room temperature, of the absorption edge depends largely on the method of manufacture of the specimen and on its thermal history. The position of the edge can be shifted by up to 0.5 ev by means of tempering; this is due to a shift of the exponential part of the absorption curve. The relation between the position of the absorption edge and electrical conductivity is also investigated. The results are discussed with reference to the crystal lattice.

535.215.3:538.639:[546.28+546.289 3231

**Photomagnetoelectric Effect in Germanium and Silicon**—H. Bulliard. (*Phys. Rev.*, vol. 94, pp. 1564–1566; June 15, 1954.) A study of the initial transient part of the effect in Ge indicates that the photomagnetoelectric voltage passes through a maximum before reaching its steady-state value. Results of some experiments on Si are also reported. See also 2015 and 2016 of 1953 (Aigrain and Bulliard).

535.215.3:538.639:546.561-31 3232

**Photomagnetic Effect in Cuprous Oxide at Low Temperatures**—A. P. Komar, N. M. Reinov and S. S. Shalyt. [*Compt. Rend. Acad. Sci.* (*URSS*), vol. 96, pp. 47–48; May 1, 1954. In Russian.] Results are reported of measurements at 4.2 degrees K and 77 degrees K in fields up to 24,000 oersted. The maximum photomagnetic emf observed at 4.2 degrees K in a sample 40 mm long was ~90v. The results are shown graphically and briefly discussed.

535.215.3:538.639:546.682.86 3233

**Photoconductivity and Photoelectromagnetic Effects in InSb**—S. W. Kurnick, A. J. Strauss and R. N. Zitter. (*Phys. Rev.*, vol. 94, p. 1791; June 15, 1954.) Brief account of experiments; results are in agreement with theory developed by Moss et al. (748 of April).

535.37 3234

**Phosphors Emitting Infrared Radiation**—G. F. J. Garlick and M. J. Dumbleton. (*Proc. Phys. Soc.*, vol. 67, pp. 442–443; May 1, 1954.) Eight phosphors with emission spectra in the infrared region beyond 1 $\mu$ have been produced, viz., $Cu_2O$, PbS, CdSe-Cu, ZnS-Cu, ZnS-Co, CdS-Cu, CdSHgS-Cu, and HgS.

535.37 3235

**Luminescence of the System $\beta Zn_3(PO_4)_2 - CD_3\ (PO_4)_2$:Mn**—A. L. Smith and A. D. Power. (*Jour. Electrochem. Soc.*, vol. 101, pp. 244–247; May, 1954.)

535.37 3236

**Sensitized Luminescence of $CaF_2$:(Ce +Mn)**—R. J. Ginther. (*Jour. Electrochem. Soc.*, vol. 101, pp. 248–257; May, 1954.)

535.37:535.341 3237

**Determination of the Absorption Coefficient of Phosphor Powder**—V. V. Antonov-Romanovski. (*Zh. Eksp. Teor. Fiz.*, vol. 26, pp. 459–472; April, 1954.) The absorption coefficient is determined from measurements of the diffuse-reflection coefficient, which is defined, and the known linear dimensions of the crystallites and the bulk-material refraction coefficient. The theory, based on that by Z. Bodó (*Acta Phys. hungarica*, vol. 1, pp. 135–150; 1951.), treats the phosphor layer as a pile of plane parallel homogeneous layers, and is developed for crystals of regular and of irregular form, i.e. one in which total internal reflection can occur. The calculated and experimentally determined results are compared and discussed in detail; actual phosphor layers include crystals of both regular and irregular shape.

535.37:537.228 3238

**Interpretation of Electroluminescence Effects in an Excited Phosphor**—F. Matossi. (*Phys. Rev.*, vol. 94, pp. 1151–1156; June 1, 1954.) See 2284 of 1953.

535.37:546.472.21 3239

**Dependence of Absorption and Luminescence Spectra of ZnS-Cu Phosphor on Cu Concentration**—M. N. Alentsev and A. A. Cherepnev. (*Zh. Eksp. Teor. Fiz.*, vol. 26, pp. 473–478; April, 1954.) Analysis of the experimental results, which are shown graphically, indicates that the blue luminescence which occurs in the presence of excess Cu is due to a restoration of the pure ZnS luminescence and not to formation of new Cu luminescence centers.

535.376:546.431-31 3240

**Cathodoluminescence Study of (BaSr)O**—K. Noga and K. Nakamura. [*Jour. Phys. Soc.* (*Japan*), vol. 9, pp. 435–437; May/June, 1954.] Luminescence was excited by bombarding BaO, SrO and (BaSr)O films with a 250-v 2-ma electron beam. The bands in the (BaSr)O spectrum lay between the corresponding bands for BaO and SrO, thus supporting the view that the (BaSr)O is a homogeneous solid solution.

537.224 3241

**Electret**—C. Yamanaka. [*Jour. Phys. Soc.* (*Japan*), vol. 9, p. 425; May/June, 1954.] A brief report of experiments on carnauba-wax electrets; the results indicate that the effect depends on the ionization of the edges of the element as well as on the ionization of the interelectrode region.

537.224 3242

**Studies of the Heterocharges of Electrets**—S. Wikström. (*Ark. Fys.*, vol. 7, part 3, pp. 213–220; March 4, 1954.) See 1071 of May.

537.227 3243

**Possible Mechanism of Ferroelectric Domain Boundary Movement**—T. Nakamura. [*Jour. Phys. Soc.* (*Japan*), vol. 9, pp. 425–426; May/June, 1954.]

537.227:546.431.824-31 3244

**The Properties of Colloidal Ferroelectric Materials: Part 3—Barium Titanate $BaTiO_3$**—M. Anliker, H. R. Brugger and W. Känzig. (*Helv. Phys. Acta*, vol. 27, pp. 99–124; May 1, 1954. In German.) Investigations by means of X-ray diffraction, electron diffraction, electron microscopy and dielectric measurements are reported. The ferroelectric properties change gradually with crystal size. The transition from the polarized (tetragonal) phase to the unpolarized (cubic) phase occupies a temperature range which increases as particle size decreases. The tetragonal spontaneous strain does not completely vanish even at temperatures some hundreds of degrees above the Curie point of the macroscopic crystal (120 degrees C.). Deviations from normal ferroelectric behavior are ascribed to structural differences between the interior and a surface layer of thickness about 100Å. Part 2:1445 of June.

537.227:546.431.824-31 3245

**Domain Clamping Effect in Barium Titanate Single Crystals**—M. E. Drougard and D. R. Young. (*Phys. Rev.*, vol. 94, pp. 1561–1564;

June 15, 1954.) Permittivity measurements were made on crystals subjected simultaneously to a varying bias voltage and to a much weaker 20-kc voltage. An observed decrease of permittivity with decrease of average polarization is interpreted as due to a multidomain clamping effect.

537.227:546.817.831.4 3246
**Threshold Field and Free Energy for the Antiferroelectric-Ferroelectric Phase Transition in Lead Zirconate**—A. P. deBretteville, Jr. (*Phys. Rev.*, vol. 94, pp. 1125–1128; June 1, 1954.)

537.228.1 3247
**Piezoelectric Properties of Lead Zirconate-Lead Titanate Solid-Solution Ceramics**—B. Jaffe, R. S. Roth and S. Marzullo. (*Jour. Appl. Phys.*, vol. 25, pp. 809–810; June, 1954.) Brief report of some experimental studies of the dependence of the piezoelectric properties on the composition of the solution and on temperature.

537.228.1:548.0 3248
**Elastic and Piezoelectric Coefficients of Dipotassium Tartrate (DKT)**—R. Bechmann and S. Ayers. (*Proc. Phys. Soc.*, vol. 67, pp. 422–426; May 1, 1954.) The constants were determined by the method of Bechmann (128 of 1951), and their variation with temperature measured. A table is included comparing the properties of some zero-temperature-coefficient cuts of DKT, EDT and quartz.

537.311.31:539.234 3249
**Hysteresis Phenomena exhibited by Rectifier Contacts and by Thin Films**—N. Nifontoff. [*Compt. Rend. Acad. Sci.*, (*Paris*), vol. 239, pp. 31–33; July 5, 1954.] Observed hysteresis of the $I/V$ curves is attributed to the diffusion of impurity ions in metal/semiconductor barriers under the influence of applied voltage.

537.311.33 3250
**Bound States in Dislocations**—R. Landauer *Phys. Rev.*, vol. 94, pp. 1386–1388; June 1, 1954.) An estimate is made of the trapping energy associated with elastic distortions.

537.311.33 3251
**Graphical Representation of the Semiconductor Hall Effect**—L. P. Hunter. (*Phys. Rev.*, vol. 94, pp. 1157–1160; June 1, 1954.) "The semiconductor Hall effect is represented in terms of an ellipse relating the Hall mobility and resistivity. Various uses and extensions of this representation are given which serve to correlate the important features of the Hall effect in semiconductors. The effects of excess current carrier lifetime and the non-equality of Hall and drift mobility ratios are discussed."

537.311.33 3252
**Some Experiments on Semiconducting Powders**—G. G. E. Low. [*Research* (*London*), vol. 7, p. S22; April, 1954.] The thermoelectric powers of *n*-type Ge and PbS and of *p*-type Ge, Si, and PbS were measured for various grain sizes and the results are shown graphically. With decreasing grain size, both magnitude and sign of the thermoelectric power changed for *n*-type materials, but only the magnitude changed for *p*-type materials, Ge and Si showing a decrease and PbS an increase.

537.311.33:538.63 3253
**New Galvanomagnetic Effect**—C. Goldberg and R. E. Davis. (*Phys. Rev.*, vol. 94, pp. 1121–1125; June 1, 1954.) If a crystal carrying an electric current is placed in a magnetic field, an electric field will be induced normal to the current in the plane defined by the directions of the current and the magnetic field. The effect is termed planar Hall effect. Measurements on Ge single crystals are reported.

537.311.33:546.28 3254
**Spin Resonance of Donors in Silicon**—R. C. Fletcher, W. A. Yager, G. L. Pearson, A. N. Holden, W. T. Read and F. R. Merritt. (*Phys. Rev.*, vol. 94, pp. 1392–1393; June 1, 1954.) Resonances were observed only in arsenic-doped Si samples which had been plastically deformed by compression at 1,000 degrees C.

537.311.33:546.28 3255
**Floating Zone Recrystallization of Silicon**—P. H. Keck, W. Van Horn, J. Soled and A. MacDonald. (*Rev. Sci. Instr.*, vol. 25, pp. 331–334; April, 1954.) A method is described for zone melting and recrystallizing Si by induction heating. Single crystals with resistivities up to several hundred ohm. cm have been grown in this way.

537.311.33:546.28:535.215 3256
**Photoconductivity in Gold-Doped Silicon**—R. Newman. (*Phys. Rev.*, vol. 94, pp. 1530–1531; June 15, 1954.) Measurements on *p*-type Si at temperatures of 20 degrees, 77 degrees and 195 degrees K are reported.

537.311.33:546.289 3257
**Conductivity and Hall Effect in the Intrinsic Range of Germanium**—F. J. Morin and J. P. Maita. (*Phys. Rev.*, vol. 94, pp. 1525–1529; June 15, 1954.) Measurements over the temperature range 250 degrees–1,000 degrees K are reported; the results are in good agreement with theory taking account of (a) the lattice-scattering mobility as determined between 100 degrees and 300 degrees and extrapolated to 1,000 degrees K, (b) scattering by electron-hole collisions, (c) correction of carrier concentration for the change in energy gap width due to es interaction of the carriers at temperatures over 500 degrees K.

537.311.33:546.289 3258
**Photon-Radiative Recombination of Electrons and Holes in Germanium**—W. van Roosbroeck and W. Shockley. (*Phys. Rev.*, vol. 94, pp. 1558–1560; June 15, 1954.) The spectral distribution of photon generation resulting from recombination is determined from the known optical properties of Ge by applying the principle of detailed balance. The value found for the thermal-equilibrium recombination rate at 300 degrees K is $1.57 \times 10^{13}$ $cm^{-3}$ $second^{-1}$. The temperature dependence of this and related parameters is shown graphically.

537.311.33:546.289 3259
**Recombination of Holes and Electrons at Lineage Boundaries in Germanium**—F. L. Vogel, W. T. Read and L. C. Lovell. (*Phys. Rev.*, vol. 94, pp. 1791–1792; June 15, 1954.) Report of measurements made by the Morton-Haynes method described by Valdes (741 of 1953), in which carriers are liberated by light.

537.311.33:546.289 3260
**Diffusion of Impurities in Germanium**—W. C. Dunlap, Jr. (*Phys. Rev.*, vol. 94, pp. 1531–1540; June 15, 1954.) Account of an experimental investigation using a method described previously [3134 of 1952 (Dunlap & Brown)], in which diffusion is determined by observing the formation of *p-n* junctions. The impurities studied were In, Ga, Al, As, B, P, Sb and Zn. Diffusion coefficients ranging from $10^{-12}$ $cm^2$ to $10^{-9}$ $cm^2$ at 900 degrees C. were found. The method is applicable to the study of surface and grain-boundary diffusion; the circumstances in which it is more suitable than the radioactive-tracer method are indicated.

537.311.33:546.289 3261
**Measurement of the Surface Properties of Germanium**—J. B. Gunn. (*Proc. Phys. Soc.*, vol. 67, pp. 409–421; May 1, 1954.) "External contacts" are defined as those in which a relatively low-resistance contact is made to the semiconductor surface layer without disturbing its properties. Three types are described: (a) electroplated Cu contacts to which connection is made either mechanically or by soldering at 80 degrees C., (b) contacts of Ag dust either in the form of a conducting paint or used dry in a hole in a perspex block with a steel plunger pressing it against a Ge disk, and (c) contacts of aqueous electrolyte either absorbed in a disk of filter paper or in liquid form. Preliminary results of measurements involving these techniques indicate the existence of a transversely conducting layer separated from the interior of the Ge specimen by a rectifying barrier, but do not support the view that the inverse properties of point contacts can be simply related to those of the surface junction. A Ge filament transistor with one "internal" and three "external" contacts and capable of power amplification is described.

537.311.33:546.289 3262
**Seebeck Effect in Germanium**—T. H. Geballe and G. W. Hull. (*Phys. Rev.*, vol. 94, pp. 1134–1140; June 1, 1954.) Measurements have been made over the temperature range 20 degrees–375 degrees K on a series of Ge single crystals having various excess amounts of either acceptor or donor atoms. Measured values of Seebeck voltage show a remarkable rise as the temperature is lowered below room temperature. Existing theory cannot account for this, and an alternative explanation is proposed based on theory to be published by Herring.

537.311.33:546.289 3263
**Energy of the High-Lying Acceptor Level in Copper-Doped Germanium**—J. F. Battey and R. M. Baum. (*Phys. Rev.*, vol. 94, p. 1393; June 1, 1954.) Results of measurements are consistent with the premise of a partially populated level at about 0.3 ev above the valence band.

537.311.33:546.289 3264
**Pressure Dependence of the Resistivity of Germanium**—W. Paul and H. Brooks. (*Phys. Rev.*, vol. 94, pp. 1128–1133; June 1, 1954.) The resistivity of a sample of 35-Ω. cm Ge has been investigated at pressures up to 30,000 $kg/cm^2$ over the temperature range 25 degrees–76 degrees C., and at pressures up to 7,000 $kg/cm^2$ at temperatures down to −195 degrees C. The results indicate an increase in total energy gap up to 15,000 $kg/cm^2$, and, for *n*-type material, a rapid rise in resistivity above that pressure. Alternative theoretical explanations are considered.

537.311.33:546.289 3265
**The Change of the Refractive Index of Some Germanium Films Irradiated by Intense Light**—K. Ishiguro and T. Hayashi. [*Jour. Phys. Soc.* (*Japan*), vol. 9, pp. 387–391; May /June, 1954.] Measurements were made on evaporated films of Ge, using a Rayleigh-Löwe interferometer. The refractive index increased when the color temperature of the source was about 3,000 degrees K and decreased when the temperature was about 1,000 degrees K. The effects are attributed to variation of the number of bound electrons.

537.311.33:546.482.21:535.215 3266
**Interpretation of the Abnormal Variation of the Photoconductivity of CdS as a Function of Illumination**—G. Wlérick. [*Compt. Rend. Acad. Sci.* (*Paris*), vol. 238, pp. 2514–2516; June, 1954.] The nonlinearity of the conductivity/illumination curve is explained on the basis of an electron recombination mechanism involving thermal transitions.

537.311.33:546.482.21:535.215 3267
**Significance of Deep Traps in the Formation of the Photoelectric Signal in Thin Films of Cadmium Sulphide**—G. Wlérick. [*Compt. Rend. Acad. Sci.* (*Paris*), vol. 239, pp. 257–259; July 19, 1954.]

537.311.33:546.682.19 3268
**Electrical Properties of InAs**—O. G. Folberth, R. Grimm and H. Weiss. (*Z. Naturf.*,

vol. 8a, p. 826; December, 1953.) Conductivity and Hall-effect measurements are reported which confirm the semiconductor properties of InAs. The mobility of the electrons is about 50 times that of the holes.

**537.311.33:546.682.86** 3269

**Significance of Conductivity Measurements on InSb**—O. G. Folberth and O. Madelung. (*Z. Naturf.*, vol. 8a, pp. 673–675; October, 1953.) Experimental results reported by Weiss (2707 of October) and by Tanenbaum and Maita (758 of April) are interpreted on the basis of curves showing the isothermal variation of conductivity as a function of electron or hole concentration.

**537.311.33:546.86:539.234** 3270

**Semiconducting Films of Antimony**—J. Cohen. (*Jour. Appl. Phys.*, vol. 25, pp. 798–801; June, 1954.) A study was made of the electrical properties of thin films of Sb condensed onto surfaces at various temperatures. Negative temperature coefficients of resistance were found for films deposited on very cold surfaces. In general, reversible resistance changes occurred if the films were cooled below a temperature previously reached, while irreversible changes occurred if the films were heated above the temperature at which they were prepared. Neither the evaporation rate nor the thickness appeared to affect the activation energy. The observed effects are explained in terms of lattice-defect theory.

**538.221** 3271

**Influence of the Thickness of the Weiss Domains on the Permeability of Iron between 0 and 7,000 Mc/s**—J. Benoit and E. Naschke. [*Compt. Rend. Acad. Sci.* (*Paris*), vol. 238, pp. 2404–2405; June 21, 1954.] Continuation of work described previously (2984 of November). The thickness of the domains was determined from permeability measurements on Armco wires treated at various temperatures. The dependence of permeability on domain thickness disappears as the frequency is increased.

**538.221** 3272

**Magnetic Viscosity in Precipitation Alloys: FeNiAl, $Fe_2NiAl$ and Alnico**—J. H. Phillips, R. Street, and J. C. Woolley. (*Phil. Mag.*, vol. 45, pp. 505–523; May, 1954.)

**538.221:621.318.134** 3273

**Thermomagnetic Investigation of Gadolinium Ferrite**—R. Pauthenet and P. Blum. [*Compt. Rend. Acad. Sci.* (*Paris*), vol. 239, pp. 33–35; July 5, 1954.] Measurements were made of the spontaneous magnetization of $Fe_2O_3 \cdot Cd_2O_3$ at field strengths up to 19,600 oersted, over the temperature range 4 degrees–700 degrees K, using a method described previously [1397 of 1953 (Pauthenet)]. The magnetization falls to zero at three points in this temperature range.

**538.221:621.318.134** 3274

**Thermomagnetic Study of Ferrites of Dysprosium and Erbium**—G. Guiot-Guillain, R. Pauthenet and H. Forestier. [*Compt. Rend. Acad. Sci.* (*Paris*), vol. 239, pp. 155–157; July 12, 1954.] Experimental results indicate that the magnetic properties of these ferrites are closely similar to those of gadolinium ferrite.

**538.221:621.318.134** 3275

**Interpretation of Magnetic Properties of Rare-Earth Ferrites**—L. Néel. [*Compt. Rend. Acad. Sci.* (*Paris*), vol. 239, pp. 8–11; July 5, 1954.] The interpretation is based on splitting the lattice into a ferrimagnetic Fe-ion sublattice weakly coupled to a paramagnetic rare-earth-ion sublattice.

**538.652** 3276

**The Approach to Saturation Magnetostriction**—L. Néel. (*Jour. Phys. Radium*, vol. 15, pp. 376–378; May, 1954.) Discussion of theory developed by Lee (2988 of November).

**538.652** 3277

**Contribution to the Study of Magnetostriction**—R. Vautier. [*Ann. Phys.* (*Paris*), vol. 9, pp. 322–372; May/June, 1954.] Theory is presented, taking account of the various elementary phenomena contributing to the overall magnetostrictive effect. Apparatus for measuring the effect is described and measurements on Fe and Ni single crystals, Co ferrites, and mixed Mn-Zn ferrites are reported. Constrained magnetostriction is recognized as distinct from spontaneous magnetostriction in the Fe and Ni crystals; the two may act in opposite senses. Measurements in strong fields are necessary to observe the phenomena clearly. In the case of Co ferrites, measurements of the temperature variation of magnetostriction may afford a useful method for investigating the mechanism of magnetization. The measurements on high-$\mu$ ferrites indicate that there is no simple relation between permeability and magnetostriction.

**546.431.824–31** 3278

**Phase Transitions in some Solid Solutions having Ferroelectric Properties**—G. A. Smolenski and V. A. Isupov. [*Compt. Rend. Acad. Sci.* (*URSS*), vol. 96, pp. 53–54; May 1, 1954. In Russian.] Results are reported for (a) $BaSnO_3$ in $BaTiO_3$, (b) $BaZrO_3$ in $BaTiO_3$ and (c) $SrTiO_3$ in $BaTiO_3$. The four states observed in (a) and (c) correspond to the cubic, tetragonal, orthorhombic and rhombohedral structure, respectively.

**621.315.616:621.315.212** 3279

**Use of Foamed Materials for Insulation in High-Frequency Coaxial Cables**—L. Krugel. (*Fernmeldetech. Z.*, vol. 7, pp. 221–226; May, 1954.) Foamed insulating materials having a polystyrol base may be used for television coaxial cables provided that special precautions are taken to prevent mechanical deformation of the cable. Other applications are limited by the mechanical properties.

**621.791.9:537.311.33** 3280

**Some Techniques for making Stable Nonrectifying Contacts to Germanium and other Semiconductors**—W. M. Mitchell. (*Jour. Sci. Instr.*, vol. 31, pp. 147–148; April, 1954.) For welding fine wires to either PbS, PbSe, or PbTe, an 80-$\mu F$ capacitor charged to 15v is discharged through the crystal and the wire, the discharge being repeated at higher voltage until contact resistance is between 1 and 10Ω. For connection to Ge, the end of the wire must be tinned, and lactic acid applied at the connection before discharging the capacitor.

## MATHEMATICS

**517** 3281

**Addition Theorems for Spherical Waves**—B. Friedman and J. Russek. (*Quart. Appl. Math.*, vol. 12, pp. 13–23; April, 1954.) The problem considered is the determination of the scattered field when a plane wave is incident on a configuration of spheres. The first-order approximation is obtained by taking the excitation field to be the initial plane wave plus the zero-th order approximation to the scattered field. To carry out this approximation the scattered field from a sphere with centre $O$ must be decomposed into incoming spherical waves for a second sphere with centre $O'$. Expansions of spherical wave functions for this purpose are derived.

**517.7** 3282

**Common Elliptic Integrals and Functions**—R. Cazenave. (*Ann Télécommun.*, vol. 9, pp. 103–108; April, 1954.) A brief survey of the theory of elliptic functions and certain of their geometrical applications.

**517.7** 3283

**Calculation of Common Elliptic Integrals and Functions**—R. Cazenave. (*Ann. Télécommun.*, vol. 9, pp. 141–155; May, 1954.) Detailed exposition of interpolation and direct methods of evaluating Legendre integrals and Jacobi functions such as occur in potential and field problems. Degrees of approximation involved and ranges of validity are indicated. *See* also 3282 above.

**517.944.3** 3284

**A Transform Method for Linear Time-Varying Systems**—J. A. Aseltine. (*Jour. Appl. Phys.*, vol. 25, pp. 761–764; June, 1954.) A method is described for finding new transformations applicable to one-point boundary-value problems. Examples of transformations derived, including Laplace, Mellin and Meijer, are presented.

**519.24:530.162** 3285

**The Representation of Stationary Statistical Functions**—R. Becker. (*Z. angew. Phys.*, vol. 6, pp. 231–235; May, 1954.) From the Fourier integral representing a stationary random process with average value zero, the relation between spectral distribution, correlation and mean square value over a fixed time interval is derived. Its application in calculations relating to shot effect, Brownian motion and resistance noise is illustrated.

**519.272** 3286

**Generalization of the Wiener-Khintchine Theorem to Nonstationary Processes**—D. G. Lampard. (*Jour. Appl. Phys.*, vol. 25, pp. 802–803; June, 1954.)

## MEASUREMENTS AND TEST GEAR

**621.3.018.41(083.74)+529.786** 3287

**Atomic Clocks and Frequency Standard on an Ammonia Line: Part 1**—K. Shimoda, [*Jour. Phys. Soc.* (*Japan*), vol. 9, pp. 378–386; May/June, 1954.] "Various causes of errors in an atomic clock utilizing the 3–3 line of ammonia are examined theoretically and experimentally. A brief description of a Stark modulation atomic clock designed for experimental purposes is given. It is shown that the fractional error will exceed 1 part in $10^{-8}$, unless high degree of frequency-insensitive multiplier output and excellent matching of waveguide to generator and detector are achieved."

**621.3.018.41(083.74)+621.396.91** 3288

**Precision Quartz Resonator Frequency Standards**—J. M. Shaull and J. H. Sheaf. (PROC. I.R.E., vol. 42, pp. 1300–1306; August, 1954.) Description of the N.B.S. primary standard of frequency. See 1731 of 1953.

**621.3.018.41(083.74)+621.396.91** 3289

**Standard Frequency Transmissions**—L. Essen. (*Proc. IEE*, part III, vol. 101, pp. 249–255; July, 1954.) A short historical résumé of standard frequency transmissions is given, and the results achieved with the British 0.5-kw MSF transmissions are discussed, with particular reference to the accuracies to be expected, both for the frequencies and the timing pulses transmitted. Coverage over the area within a radius of about 1,000 miles is satisfactory.

**621.317.3:621.396.621.029.6:621.396.822** 3290

**A Continuous Monitor of Microwave Receiver Noise-Factor**—R. D. Holland and N. A. Godel. (*Jour. Brit. IRE*, vol. 14, pp. 322–331; July, 1954.) Technique described by Dicke for the measurement of microwave radiation (475 of 1947) is adapted. A small modulated noise signal is introduced into the receiver, a sample of the IF output is detected, and voltages in a narrow band around the modulation frequency are selected and amplified. This composite signal is applied to a coherent detector followed by a low-pass filter whose output is shown on a meter calibrated to give the noise factor. A design for use with an *S*-band radar system is described.

**621.317.3.029.63/.64** 3291

**Simplified Method for the Determination**

**of the Material Constants ($\epsilon$, $\mu$, $\sigma$, tan $\delta$) for Solid, Liquid and Gaseous Substances, especially for Small Samples**—A. Esau and D. Prösdorf. (*Naturwiss.*, vol. 41, p. 208; May, 1954.) The method is for use at decimeter wavelengths, and involves measurement of the node displacement caused by introduction of the sample, in a suitable container, into a coaxial line. Trolitul is recommended for the container material. Approximate formulas are derived from which the required physical constants can be simply calculated. Samples smaller than 1 cm³ can be dealt with. The method can also be used for determining the thickness of thin metal layers. At centimeter wavelengths the same method can be used with waveguides.

621.317.321 3292

**Measuring Small Voltage Changes**—J. P. Salter. (*Wireless World*, vol. 60, p. 451–453; September, 1954) Changes of the order of 0.1 v in the dc level of a relatively high voltage can be measured by means of a circuit which in its basic form comprises a low-grid-conductance electrometer tube and a polystyrene-film capacitor, with polystyrene-insulated switch. Detailed practical circuits are shown, including a bridge arrangement for mains operation.

621.317.34.018.75:621.315.212 3293

**0.05-Microsecond Pulse Echo Meter for Investigating Impedance Uniformity in 5/18 Coaxial Pairs**—P. Herreng. (*Cables & Trans.*, vol. 8, pp. 172–189; April, 1954.) Principles of the technique are given and equipment recently developed for tests on production lengths of cable is described. Pulses are trapezoidal, with rise time of 0.015 $\mu$s. Using distributed amplification in the receiver a gain of 68 db is attained at frequencies up to 80 mc. Results of measurements made with pulses of duration 0.1 and 0.05 $\mu$s are compared; more detailed oscillograms are obtained with the shorter pulses.

621.317.38.029.64 3294

**On Microwave Power Measurements**—E. Weber. (*Elektrotech. u. Maschinenb.*, vol. 71, pp. 254–259; May 1, 1954. In English.) Bolometer bridge arrangements are discussed. The observed nonlinear variation of resistance with bias power in a Wollastonwire bolometer follows readily from the complete solution for the temperature distribution using the Langmuir formula for the cooling of thin wires. Measurements of microwave power by the superposition principle are subject to slight errors on account of this nonlinearity. If the ratio of bolometer wire length to $\lambda$ is kept below 0.1 the error can be kept to $<2$ per cent.

621.317.42 3295

**The Measurement of Two-Dimensional Fields: Part 1—Theory**—W. C. Elmore and M. W. Garrett. (*Rev. Sci. Instr.*, vol. 25, pp. 480–485; May, 1954.) A two-dimensional magnetic field may be uniquely specified by listing all coefficients of the power-series expansion of its complex potential function. Experimentally, the first $N$ coefficients may be derived from an $N$-point harmonic analysis of the radial component of field or gradient, as measured with a dipole or quadrupole search coil at $N$ equally spaced angular positions about an arbitrary longitudinal axis. Refinements of the method for the determination of higher harmonics are discussed.

621.317.42:535.56 3296

**Application of the Faraday Effect to Measurement of Magnetic Fields**—F. Hock. (*Z. angew. Phys.*, vol. 6, pp. 151–153; April, 1954.) Use is made of the high Verdet's constant of magnetically saturated iron (382–500 degrees/cm ± 2 per cent) in the polarimeter-type instrument described. The rotation of the plane of polarization of light by a semitransparent iron layer 1 $\mu$ thick, deposited on a 3 mm diameter quartz disk, and placed inside a magnetic lens under test, is approximately 3.8 degrees in an 18,000-gauss field.

621.317.42:621.384.612 3297

**The Measurement of Two-Dimensional Fields: Part 2—Study of a Quadrupole Magnet**—I. E. Dayton, F. C. Shoemaker and R. F. Mozley. (*Rev. Sci. Instr.*, vol. 25, pp. 485–489; May, 1954.) Measurements on a quadrupole magnet for use in the design study of the strong-focusing synchrotron were made using the method of 3295 above.

621.317.45 3298

**The Nondestructive Read-Out of Magnetic Cores**—A. Papoulis. (Proc. I.R.E., vol. 42, pp. 1283–1288; August, 1954.) See 2468 of September (Buck and Frank).

621.317.7:621.314.6 3299

**Rectifiers in Electrical Measurements. Limits of the Field of Application**—H. Pfannenmuller. (*Arch. tech. Messen.* pp. 119–122; May, 1954.) A survey of the uses of various types of rectifiers in measurement circuits.

621.317.71/.72 3300

**Multirange, Audiofrequency Thermocouple Instruments of High Accuracy**—F. L. Hermach and E. S. Williams. (*Jour. Res. Nat. Bur. Stand.*, vol. 52, pp. 227–234; May, 1954.) Two new instruments are described. The first, called a volt-ampere converter, is used with a dc potentiometer to make measurements of alternating voltage and current over wide ranges accurate to within 0.05 per cent at frequencies up to 20 kc. The second is a multirange thermocouple volt-ammeter accurate to within 0.5 per cent and incorporating simple circuits so that the thermal converter may be checked with the indicating instrument normally connected to it.

621.317.714 3301

**An R.M.S. Milliammeter of Novel Design for the Measurement of Current from Zero to Video Frequencies**—H. B. Wood. (*Jour. Sci. Instr.*, vol. 31, pp. 124–125; April, 1954.) Two thermistors form adjacent arms in a Wheatstone bridge. The current to be measured is applied to one thermistor, the temperature rise of which is proportional to the mean-square value of the input current. The unbalance current is passed to a dc amplifier, and thence via a moving coil ammeter to the second thermistor, thus tending to restore the bridge balance. The ammeter indicates true rms current on a linear scale up to 10 ma; this range may be extended. The accuracy of indication is within ±2 per cent of full-scale deflection for frequencies from 0 to 7 mc falling by 4 per cent of 10 mc.

621.317.714.029.62 3302

**Thermocouple-Type Ammeters for Use at Very High Frequencies**—O. G. McAninch. (*Elect. Eng.*, vol. 73, pp. 431–435; May, 1954.) Sources of error in thermocouple instruments at high frequencies are discussed. Skin effect, impedance and resonance effects are reduced in an experimental design described. It incorporates short concentric terminals and a thin ribbon heating element folded back on itself, with mica insulation between the two halves and the hot junction welded to the mid-point near the fold. The impedance of the instrument is about 6Ω, it is consistently inductive and has no resonance points below 200 mc. To be published also in *Trans. Amer. Inst. Elect. Eng. Communication and Electronics*, 1954.

621.317.72 3303

**An Electric Field Meter with Extended Frequency Range**—L. G. Smith. (*Rev. Sci. Instr.*, vol. 25, pp. 510–513; May, 1954.) A field-mill type meter is described which has two complementary sets of stators, so arranged as to ensure that a constant area is exposed to the field. Thus hf components up to 22 kc can be detected. Two ranges of sensitivity are provided, for maximum fields of 800 and 16,000 v/cm respectively. The instrument may also be used to measure potential at very high impedance.

621.317.729:537.291 3304

**Automatic Electron Trajectory Plotting using the Electrolytic Tank Analogue**—B. O. Baker. (*Brit. Jour. Appl. Phys.*, vol. 5, pp. 191–195; May, 1954.)

621.317.75 3305

**Design Planning of Equipment for the Visual Observation of Spectra of Electrical Oscillations**—S. M. Khlytchiev. [*Radiotekhnika (Moscow)*, vol. 9, pp. 38–46; May/June, 1954.] Frequency-sweep spectrometers for rf and af are considered. The preliminary considerations, such as the choice of the optimum oscillator frequency and the rate of change with time, and the shape of the cro timebase pulse, are discussed quantitatively and some circuit details are given. The characteristics of apparatus for rf and af operation are summarized, the former covering the range 500 cps–15 mc in 9 bands, the latter the ranges 200 cps–5, 10, or 20 kc.

621.317.75:621.396.3 3306

**Radio Spectroscope**—A. Tchernicheff. (*Ann. Télécommun.*, vol. 9, pp. 116–120; April, 1954.) An instrument for analysing the spectrum of radiotelegraph signals of any waveform at transmission speeds ≧50 bauds. See 3056 of 1951.

621.317.772 3307

**An Audio Frequency Phase Meter**—F. P. Moss. (*Electronics Eng.*, vol. 26, pp. 361–363; August, 1954.) Each of the two sine waves whose phase is to be compared is passed through a limiter circuit of the type described by Johnson (3175 above) in which it is converted to a square wave of unity mark/space ratio. The phase-difference reading is thus rendered largely independent of variations of signal level and even-harmonic distortion.

621.397.62.001.4 3308

**Measurements on Television Receivers: Part 3—Measurement of Transmission Characteristics in the Video-Frequency Circuits**—Macek. (*See* 3376).

## OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534.1.082.74 3309

**A Self-Contained Electrical Vibration Meter—the Sinus Vibrometer**—A. Johansson. [*IVA (Stockholm)*, vol. 25, no. 5, pp. 204–208; 1954.] The instrument described has an electrodynamic pickup with permanent magnet, and uses the energy of the vibration under examination as its only power supply. Accuracy is good enough for laboratory measurements.

534.321.9 3310

**Ultrasonic Developments**—(*Wireless World*, vol. 60, pp. 448–450; September, 1954.) Brief review of various special-purpose ultrasonic echo-sounding equipments, some of which were discussed at the Oxford convention of the British IRE while others were shown at the Manchester exhibition of the Institution of Electronics. A beam-steering system using a transducer with a multisection $BaTiO_3$ line associated with an $LC$ delay line is described.

534.321.9:620.179.1 3311

**Improvements in Ultrasonic Flaw Detection**—G. Bradfield. (*Jour. Brit. IRE*, vol. 14, pp. 303–308; July, 1954.) Improvements to apparatus developed at the National Physical Laboratory are described, including (a) a mode changer made of heavy material in the form of a laminated assembly, (b) damping, loading and circuitry for piezoelectric crystals to give improved discrimination and to reduce the adverse effects of rough surfaces, and (c) ultrasonic-beam-steering devices.

536.58:621.38 3312

**A Time-Proportional Electronic Thermostat**—(*Tech. News Bull. Nat. Bur. Stand.*, vol. 38, p. 71; May, 1954.) The temperature-sensing element may be a resistance thermometer or a thermistor, and is connected in an ac bridge. The error signal together with a sawtooth voltage is applied to a synchronous detector whose output operates a trigger circuit actuating a relay in the heater circuit. Deviation from the control temperature causes variation of the fraction of the cycle during which heating power is applied. Using this device, the temperature of an oil bath has been held within ±0.001 degree C. of 28 degrees C. over a period of months.

620.17 3313

**Nondestructive Testing of Materials**—(*Z. Metallkde*, vol. 45, pp. 145–249; April, 1954.) This special issue gives papers describing ultrasonic, magnetic, electromagnetic and electronic methods of testing and sorting metals, and includes a survey of nondestructive testing methods used in America.

621–52:681.142 3314

**Statistical Computers as applied to Industrial Control**—Huggins. (*See* 3145.)

621.317.39 3315

**Industrial Metal Detectors with Special Reference to Sorting of Ores and Coal**—T. G. Charles. [*IVA* (*Stockholm*), vol. 25, no. 5, pp. 209–220; 1954.] The ASDET is a simple search-coil-type detector developed in the ASEA laboratories. A standard 4-tube amplifier, requiring no adjustment, is used in conjunction with a range of coils to cover all reasonable requirements.

621.317.727:681.142:623.55 3316

**Precision Potentiometers for Analog Computers**—D. G. Blattner. (*Bell. Lab. Rec.*, vol. 32, pp. 171–177; May, 1954.) The functions of precision potentiometers in gunlaying control systems are outlined and an illustrated description of drum and spiral types is given. Specially selected high-resistance wire is wound, 200 or 300 turns per inch, on cards varying in length from 5 to 90 inches and with a core of stress-free hard rubber ground to uniform thickness. A typical unit has an error of about 6 yards at a range of 20 miles.

621.365.54† 3317

**A Survey of Applications of British Industrial High-Frequency Induction-Heating Equipment and their Economic Aspect**—[*Metallurgia* (*Manchester*) vol. 49, pp. 223–229; May, 1954.]

621.374.32:621.387.4 3318

**A Count-Rate Meter**—E. W. Pulsford. (*Electronic Eng.*, vol. 26, pp. 356–359; August, 1954.) Details are given of a circuit embodying automatic correction for losses caused by finite resolving time.

621.383.087.252 3319

**Monitoring of High-Speed Phenomena**—F. Früngel. (*Z. angew. Phys.*, vol. 6, pp. 183–192; April, 1954.) An account is given of stroboscopic and pulsed-image-converter methods of observation of high-speed nonluminous and luminous phenomena, respectively, and applications are described and illustrated by photographs. Technical information on suitable equipment is given.

621.384.611 3320

**Concentration of a Cyclotron Beam by Strong-Focusing Lenses**—F. B. Shull, C. E. MacFarland and M. M. Bretscher. (*Rev. Sci. Instr.*, vol. 25, pp. 364–367; April, 1954.) Part of the divergent beam from the Washington University cyclotron has been concentrated by means of a pair of strong-focusing magnetic lenses, at distances up to 411 cm beyond the end of the cyclotron; increase of the beam intensity by a factor of about eight has been achieved.

621.384.611 3321

**Cyclotron Beam Energy Determination by a Time-of-Flight Method**—J. H. Manley and M. J. Jakobson. (*Rev. Sci. Instr.*, vol. 25, pp. 368–369; April, 1954.)

621.384.611 3322

**The Acceleration of Heavy Ions in a Fixed-Frequency Cyclotron**—D. Walker, J. H. Fremlin, W. T. Link and K. G. Stephens. (*Brit. Jour. Appl. Phys.*, vol. 5, pp. 157–164; May, 1954.) A mechanism of acceleration is described which leads to a continuous energy distribution of the final ions of high charge. The beam current of high-energy ions can be increased by increasing the pressure of gas in the cyclotron tank to increase the probability of stripping.

621.384.611 3323

**The University of Washington-Sixty-Inch Cyclotron**—F. H. Schmidt, G. W. Farwell, J. E. Henderson, T. J. Morgan and J. F. Streib. (*Rev. Sci. Instr.*, vol. 25, pp. 499–510; May, 1954.) An account is given of the special mechanical and electrical design features and of the steps taken to achieve satisfactory operation.

621.384.612 3324

**Magnetic Deflector for the Bevatron**—B. T. Wright. (*Rev. Sci. Instr.*, vol. 25, pp. 429–431; May, 1954.) A device designed for the production of an external proton beam from the bevatron.

621.384.612 3325

**Proposal of a Synchrotron with a Double Vacuum Chamber**—G. Salvini. (*Nuovo Cim.*, vol. 11, pp. 555–558; May 1, 1954. In English.) On the basis of the observed reduction in the diameter of the beam as its energy increases, a design is proposed in which acceleration is accomplished in two stages, the second chamber being much smaller than the first, with consequent reduction of the requirements in respect of constructional material and excitation energy.

621.384.612:621.3.078.4 3326

**A Servo-Drive for Accurate Speed Control**—D. E. Caro, J. Y. Freeman and L. U. Hibbard. (*Jour. Sci. Instr.*, vol. 31, pp. 170–173; May, 1954.) Description, including complete circuit diagram, of speed control for the rotating capacitor in the Birmingham proton-synchrotron rf system. The servo-drive system consists of a phonic motor excited by a synchronous signal picked up from the rotor teeth. The response time of the motor to applied voltages controlling the torque is 1 ms. The advantages of the phonic motor in this application are noted.

621.384.622 3327

**Determination of the Axial Field of an Alvarez-Type Linear Accelerator**—W. Chahid. [*Compt. Rend. Acad. Sci.*, (*Paris*), vol. 239, pp. 42–44; July 5, 1954.]

621.385.833 3328

**High-Resolution Replicas and Their Application**—T. Hibi and K. Yada. (*Jour. Appl. Phys.*, vol. 25, pp. 712–719; June, 1954.) Improved methods are described for preparing two-step replicas for use in electron microscopy.

621.385.833 3329

**Potential Distribution of Symmetrical Cylindrical Electron Lenses**—G. D. Archard. (*Brit. Jour. Appl. Phys.*, vol. 5, pp. 179–181; May, 1954.) "Expressions are developed for the distribution of axial potential and potential derivatives in the two-dimensional 'unipotential' electron lens. Comparison is made with expressions obtained in simpler cases, and an example is illustrated."

621.385.833 3330

**Summarized Proceedings of a Conference on Electron Microscopy—London, November 1953**—(*Brit. Jour. Appl. Phys.*, vol. 5, pp. 165–170; May, 1954.)

621.387.424 3331

**Effect of Dead Time of G-M Counter Tubes on the Direct Indication of the Time-Average of Pulse Frequency**—P. Nenning. (*Z. angew. Phys.*, vol. 6, pp. 145–150; April, 1954.)

621.43:621.376.3 3332

**Measurement of Pressure [in internal combustion engines] by Capacitor Indicator**—E. Gourski. [*Rev. HF* (*Brussels*), vol. 2, no. 10, pp. 268–270; 1954.] The variations of pressure modulate the frequency of a hf carrier. To ensure stable operation, filter and voltage-amplitude-regulator stages precede demodulation.

681.82 3333

**Electronic Music**—(*Tech. Hausmitt. NordwDtsch. Rdfunks*, pp. 4–56; 1954.) Special issue including the following papers:

"Terminology of Electronic Music,"—W. Meyer-Eppler (pp. 5–7). Definitions of the principal types of instrument are given and a classification is suggested.

"Technical Equipment of the Electronic Music Studio [in Cologne Broadcasting House],"—F. Enkel (pp. 8–15).

"Filter Circuits for the Electrical Production of Sound,"—K. H. Adams (pp. 18–23).

"Mathematical Acoustic Bases for the Composition of Electronic Music,"—W. Meyer-Eppler (pp. 29–39).

"Notation in Electronic Music,"—H. Eimert, F. Enkel and K. Stockhausen (pp 52–54).

## PROPAGATION OF WAVES

621.396.11:551.510.535 3334

**Ionospheric Absorption Measurements during a Sunspot Cycle**—Appleton and Piggott. (*See* 3220.)

621.396.11:551.594.5 3335

**Radio Echoes during Aurora**—McNamara and Currie. (*See* 3222.)

621.396.11.029.55:551.594.5 3336

**The Location of the Auroral Absorption Zone**—Agy. (*See* 3224.)

621.396.11.029.55:551.594.5 3337

**Long-Range Radio Echoes from Auroral Ionization**—Peterson and Leadabrand. (*See* 3223.)

621.396.11.029.62/.63 3338

**Basic Ground-Wave Propagation Characteristics in the Frequency Band 50–800 Mc/s**—J. A. Saxton. (*Proc. IEE*, part III, vol. 101, pp. 211–214; July, 1954. Discussion, pp. 221–224.) Full paper. See 2492 of September.

621.396.11.029.62/.63 3339

**Ground-Wave Field-Strength Surveys at 100 and 600 Mc/s**—J. A. Saxton and B. N. Harden. (*Proc. IEE*, part III, vol. 101, pp. 215–221; July, 1954. Discussion, pp. 221–224.) Full paper. See 2492 of September. See also 1928 of July (Saxton).

621.396.81 3340

**Field-Strength Calculation**—K. Suda. (*Wireless Eng.*, vol. 31, pp. 249–251; September, 1954.) A brief explanation is given of the "equivalent conductivity" method for calculating field strength over mixed paths. The equivalent conductivity is derived from Sommerfeld's "numerical distance," which in turn is determined from the path parameters. Results are in good agreement with values measured in England, Denmark and Japan.

621.396.81 3341

**Reflection Coefficients of Irregular Terrain**—K. Bullington. (Proc. I.R.E., vol. 42, pp. 1258–1262; August, 1954.) Fading due to ground reflections over radio relay paths is discussed. Considerable experimental data were obtained during the survey for the U.S. transcontinental microwave system. Variation of signal strength with aerial height was measured using 57-inch paraboloids on portable 200-foot towers, and the ground reflection coefficients were hence determined. For most of the repeater sections the value of this coefficient at 4 kmc lay between 0.2 and 0.4. No simple relation was found between the path profile and the observed reflection coefficient; the statistical relation previously pointed out by Rice (664 of 1952) is accepted.

621.396.81.029.51/.53 3342

**A Survey of Ground-Wave Propagation Conditions in South Africa**—R. W. Vice. (*Trans. S. Afr. Inst. Elect. Eng.*, vol. 45, pp. 139–156; April, 1954. Discussion, pp. 156–159.) Ground-wave propagation characteristics at frequencies up to 1 mc can be predicted with the aid of the ground-conductivity map and the conductivity/frequency curve. Norton's curves (1596 of 1942) and Millington's theory (1758 of 1949) of propagation over inhomogeneous ground were used in the determination of ground conductivity and should be used in field-strength predictions based on the ground-conductivity map given for South Africa. Deviations due to local effects were generally less than 3 db, but in mountainous terrain diffraction losses may have to be taken into consideration. Field strength variations due to time variations of ground conductivity and refraction in the atmosphere were negligible.

## RECEPTION

621.376:621.396.82 3343

**Simultaneous Detection of Signal and Interference by Amplitude Detectors and by Phase Detectors Operating in a Linear Noninertial Mode of Detection**—E. I. Manaev. [*Radiotekhnika* (*Moscow*), vol. 9, pp. 19–32; May/June, 1954.] Results are presented of a theoretical and experimental investigation of detecting signals in the presence of one or more sinusoidal interference voltages or fluctuation (noise) voltages. Simple and sufficiently accurate formulas are given showing the suppression of the noise for arbitrary correlation at the detector input. Experimental and calculated results are shown graphically.

621.396.62:621.396.812.3:519.272.15 3344

**Suppression of Fluctuation Interference in the Correlation Method of Reception**—M. I. Karnovski. [*Radiotekhnika* (*Moscow*), vol. 9,, pp. 3–11; May/June, 1954.] Expressions derived for the signal/noise ratio in the correlation method of reception [Lee et al. (730 of 1951)] and the corresponding ratio at the output of a bandpass filter are compared.

621.396.621 3345

**The High-Accuracy Logarithmic Receiver**—T. H. Chambers and I. H. Page. (Proc. I.R.E., vol. 42, pp. 1307–1314; August, 1954.) Design of receivers using the method of successive detection with progressive limiting to give output-voltage increments proportional to input-voltage ratios is discussed. Each IF stage is operated as an infinite-impedance detector with unity gain for high-level signals and as a linear amplifier for low-level signals; dc degeneration is used for stabilization. Three receivers with weak-signal bandwidths of 1.8, 6.5 and 9.5 mc respectively are described.

621.396.621:621.376.2/.3 3346

**Combination F.M./A.M. Receivers**—G. H. Russell. (*Wireless World*, vol. 60, pp. 431–436; September, 1954.) The transmission standards for the projected B.B.C. vhf FM service are indicated. 100 per cent modulation corresponds to 75 kc deviation, maximum modulation frequency is 15 kc, and pre-emphasis corresponding to a time constant of 50 $\mu$s is to be used. From a preliminary list it appears that carrier frequencies of stations serving the same area are separated by 2.2 mc. Field strength is expected to be at least 800 $\mu$v/m in towns and about 250 $\mu$v/m in the country. Receiver sensitivity of the order of 10 $\mu$v and a selectivity characteristic of $-3$ db at $\pm 150$ kc are considered acceptable. For sets receiving medium-wave and long-wave AM as well as the FM, two tuners controlled by a single knob, two IF chains and normally two detectors are required. Practical circuits are illustrated showing switching arrangements.

621.396.621.029.6:621.396.822:621.317.3 3347

**A Continuous Monitor of Microwave Receiver Noise-Factor**—Holland and Godel. (*See* 3290.)

621.396.822.1:621.396.61 3348

**A Particular Case of Cross-Modulation in the Field of High-Power Transmitters**—Schellmann and K. Vogt. (*See* 3384.)

621.396.823 3349

**Industrial Interference: Sources, Measurement and Elimination**—C. Févrot and J. F. Ulmo. (*Rev. Gén. élect.*, vol. 62, pp. 567–575; December, 1953.) Suppression of "conducted" interference by means of filters is discussed; the attenuation produced depends on the impedance of the lines in which the filters are inserted. A range of filters should be available, for various current ratings, frequency bands and attenuation values. Because of the difficulty of measuring the radiation field, the interference voltage in conductors is measured instead. Results are reported of measurements on typical electrical machinery.

## STATIONS AND COMMUNICATION SYSTEMS

621.3.018.78:621.376.3 3350

**Phase Distortion introduced by Distortion of a Frequency-Modulated Wave**—P. J. M. Clavier. (*Cables & Trans.*, vol. 8, pp. 190–194; April, 1954.) Under conditions such that Libois' quasistationary approximation (448 of 1951) is valid, the propagation time of the modulation signal does not depend on the signal frequency. For the case of echo phenomena, an approximate formula is derived giving the upper limit of delay distortion.

621.376.3/.4 3351

**Spectrum Width in Frequency and Phase Modulation**—A. M. Zaezdnyi. [*Radiotekhnika* (*Moscow*), vol. 9, pp. 47–49; May/June, 1954.] Simple approximate expressions for the spectrum width are given for signals with a modulation index between 3 and 50, the spectrum being bounded by points at which the amplitude is 1.5 or 10 per cent of the amplitude maximum.

621.376.5 3352

**Theoretical Fundamentals of Pulse Transmission: Part 2**—E. D. Sunde. (*Bell Syst. Tech. Jour.*, vol. 33, pp. 987–1010; July, 1954.) The limitation of pulse transmission rates by system imperfections is further examined, and a comparison is made of the performance of double- and vestigial-sideband systems. Limitation of channel capacity by characteristic distortion and by random noise is discussed. Part 1: 2763 of October.

621.39.001.11:621.376.5 3353

**Intermodulation in Pulse Communication Systems**—P. Marcou. (*Ann. Télécommun.*, vol. 9, pp. 122–125; May, 1954.) A general expression for the output from a square-law detector contains terms representing useful signal, noise and intermodulation products. The effect of the latter on pulse shape, position and polarity is illustrated and the general principles of decoding in the presence of noise are discussed with reference to Loeb's duality principle (2215 of August). The advantage of using ppm or pwm is indicated.

621.396.3:[621.376.52+621.376.55 3354

**Frequency Spectra of Tone Telegraphy Systems with Amplitude and Phase Keying**—L. I. Yaroslavski and A. Yu. Lev. [*Radiotekhnika* (*Moscow*), vol. 9, pp. 64–71; May/June, 1954.] The frequency spectra are calculated for the case when the rate of keying is of the order of the tone frequency used. Application of the results shows that the power contained in a signal using a $\pi/2$ phase shift is approximately 1.8 times the power contained in the corresponding AM signal of equal bandwidth.

621.396.4 3355

**Two-Channel Frequency [-shift] Radiotelegraphy**—I. F. Agapov. [*Radiotekhnika* (*Moscow*), vol. 9, pp. 50–63; May/June, 1954.] The system considered is similar to the Twinplex system described by Buff (*Elec. Commun.*, vol. 29, pp. 20–33; March, 1952). Two 2-element mark-space channels are combined to form on a frequency scale a single 4-element channel where four audio frequencies represent the four possible mark-space combinations. The basic combiner circuit is described and channel bandwidth, distortion and operating speed are discussed. The system is in use on all radio-link trunk lines in the U.S.S.R. See also 3038 of November (Buff).

621.396.5.029.63:621.396.812.3 3356

**Single-Channel System of Frequency Diversity**—D. D. Howard. (*Electronics*, vol. 27, pp. 158–161; August, 1954.) In a system for AM telephony the rf energy is spread over a uhf channel by frequency-modulating the carrier with a tone before performing the amplitude modulation. Analysis for propagation under two-path conditions indicates that the system may reduce fading over some line-of-sight paths.

621.396.712+621.396.61.029.51 3357

**Very-High-Power Long-Wave Broadcasting Station**—C. E. Smith, J. R. Hall and J. O. Welden. (Proc. I.R.E., vol. 42, pp. 1222–1235; August, 1954.) Illustrated description of the Voice of America station CAST, near Munich, which began regular operation in August, 1953. A diesel power plant gives 5.2 mw. Twin 500-kw transmitters are provided; the outputs can be used separately or combined. Over-all efficiency is $>50$ per cent. Modulation is at low level. The af response is flat within 0.5 db from 100 cps to 5 kc. A 12-inch-diameter coaxial transmission line feeds an 837-foot top-loaded tower; the ground system consists of 100 miles of No. 6 Cu wire and extends out 0.5 mile from the tower.

621.396.721.029.55 3358

**Modern Walkie-Talkie for Emergency Use**—B. Howlett. (*RSGB* Bull., vol. 29, pp. 511–512, 516; May, 1954.) Description of a 28-mc transceiver using a DCC90 double-triode, one section of which acts as oscillator/super-regenerative-detector, the other as modulator/af amplifier. A range of half a mile was obtained in a heavily built-up area with high interference level.

## SUBSIDIARY APPARATUS

541.136.22 3359

**The Behaviour of Standard Cells in Conditions which include the Generation of Appreciable Current**—L. Hartshorn and F. A. Manning. (*Jour. Sci. Instr.*, vol. 31, pp. 115–118; April, 1954.) Measurements made on Western-type standard cells generating currents of 1, 10 or 100 $\mu$A for varying periods of time are reported, from which the voltage stability attainable under these conditions may be estimated.

621.311.6:[621.314.63+621.314.7 3360
**Transistors and Junction Diodes in Telephone Power Plants**—Chase, Hamilton and Smith. (*See* 3387.)

621.311.6:621.314.7:621.387.424 3361
**Transistor Power Supply for Geiger Counters**—A. R. Pearlman. (*Electronics*, vol. 27, pp. 144–145; August, 1954.) A unit isde scribed comprising junction transistors in a class-*C* amplifier circuit, operating from a 3-v battery and supplying 5 $\mu$A at 700 v.

621.311.6:621.375.222 3362
**Bias Supplies for Direct-Coupled Circuits**—J. H. Reaves. (*Electronics*, vol. 27, pp. 172–173; August, 1954.) Details are given of power-supply arrangements using special transformers with low shunt capacitance, thus permitting operation at above-earth potentials in direct-coupled amplifiers.

621.311.6:621.385.029.64/.65 3363
**Stabilized H. V. Power Supply. Application to Millimetre-Wave Klystrons**—J. Mevel. (*Jour. Phys. Radium*, vol. 15, supplement to no. 5, pp. 109A–112A; May, 1954.) A circuit is described in which the series stabilizer tube is inductively coupled to the error amplifier. An output of 20 ma at 4 kv can be provided.

621.362:523.7 3364
**Solar Thermoelectric Generators**—M. Telkes. (*Jour. Appl. Phys.*, vol. 25, pp. 765–777; June, 1954.) Physical characteristics relevant to their usefulness for thermocouple materials have been determined for various metal alloys and compounds. The efficiencies of flat-plate-type solar-energy collectors in combination with such thermocouples is evaluated; the value of 0.63 per cent obtained using ZnSb-type alloys in combination with a Bi alloy was ten times as great as that obtained with commercially available chromel *P* in combination with constantan. Using concentrating lenses, the efficiency obtained with the best alloy combination was 3.35 per cent. The maximum economically permissible cost of thermoelectric generators is evaluated.

## TELEVISION AND PHOTOTELEGRAPHY

621.397.2 3365
**Waveform Responses of Television Links**—N. W. Lewis. (*Proc. IEE*, part III, vol. 101, pp. 258–270; July, 1954.) For testing 405-line television links having a nominal upper cut-off frequency of 3 mc, a set of four test signals has been used experimentally during the past three years with satisfactory results. All the signals have a 1-v peak-to-peak amplitude and include normal 0.3-v line-synchronising pulses of 10-$\mu$s duration and 10-kc repetition frequency. Typical examples of waveform responses are shown. Two complementary methods of specification of waveform response are proposed, one for rapid routine-test purposes and the other to meet the more precise requirements of acceptance tests. Both are framed in terms of a rating factor, the value of which can be varied to provide any desired degree of stringency.

621.397.26:621.396.65.029.64 3366
**The Manchester-Kirk o' Shotts Television Radio-Relay System**—G. Dawson, L. L. Hall, K. G. Hodgson, R. A. Meers and J. H. H. Merriman. (*Proc. IEE*, part III, vol. 101, pp. 273–275; July, 1954.) Digest of paper abstracted in 2784 of October.

621.397.5:535.623 3367
**Colour Television Broadcasting in the U.S.A.**—C. G. Mayer. (*Electronic Eng.*, vol. 26, pp. 342–347; August, 1954. *J. R. Soc. A*, vol. 102, pp. 729–744; July 23, 1954. Discussion, pp. 744–747.) An outline of the R.C.A. system and brief account of the present state of color television in the U.S.A. For details of the system see Proc. I.R.E., vol. 42; January, 1954.

621.397.5:535.623 3368
**Colour Television: some Subjective and Objective Aspects of Colour Rendering**—G. T. Winch. (*Proc. IEE*, part III, vol. 101, pp. 255–257; July, 1954.) Discussion on 1818 of 1953.

621.397.5:535.623 3369
**N.T.S.C. Signal Specifications**—(Proc. I.R.E., vol. 42, p. 1321; August, 1954.) Correction to paper noted in 1199 of May.

621.397.5(94) 3370
**Groundwork of TV Practice—the Television Code or Synchronizing Signals**—E. G. Beard. [*Philips Tech. Commun. (Australia)*, no. 2, pp. 11–17; 1954.] Includes details of the synchronizing signals specified by the Australian authorities.

621.397.611:778.5 3371
**[16-mm] Narrow-Film Scanner for Television**—H. Kante and R. Krug. (*Fernmeldetech. Z.*, vol. 7, pp. 230–231; May, 1954.) Brief description of a flying-spot film scanner, used in the Berlin-Tempelhof television station, in which the continuous film motion is compensated by means of a rotating 12-sided prism.

621.397.611:778.5:535.623 3372
**Continuous Film Scanner for Monochrome or Color**—E. H. Traub and J. F. Fisher. (*Electronics*, vol. 27, pp. 152–157; August, 1954.) Arrangements are described for using a flying-spot system with rotating-polygon optical compensation of film movement [2238 of August (Traub)] to obtain a color signal. The photoelectric head comprises three photomultipliers, two dichroic mirrors, a plane mirror, and three color filters. Gamma correction circuits are described.

621.397.62 3373
**Large Television Screen**—M. Likhachev and R. Shtromberg. [*Radio (Moscow)*, no. 5, pp. 36–38; May, 1954.] Description of the 3m×4m projection-television installation in the Moscow cinema "Ermitazh."

621.397.62:621.385.032.44 3374
**Series Heater Strings for TV Receivers**—F. Roberts. (*Electronics*, vol. 27, pp. 126–129; August, 1954.) When tube heaters are arranged in series, failures may occur as a result of current and voltage surges during the warm-up period due to inequalities in the rate of change of heater resistance. An arrangement for investigating the transients oscillographically is described. The surges can be reduced by grouping the heaters in the string on the basis of their warm-up time. (See also *Trans. I.R.E.*, No. PGBTR-7, pp. 39–46; July, 1954.)

621.397.62:621.395.5 3375
**Valves for use in Band III Television Tuners**—Hampson and Neville. (*See* 3417.)

621.397.62.001.4 3376
**Measurements on Television Receivers: Part 3—Measurement of Transmission Characteristics in the Video-Frequency Circuits**—O. Macek. (*Arch. tech. Messen*, pp. 101–104; May, 1954.) Methods of determining the amplitude/frequency, phase/frequency and pulse-transmission characteristics are briefly described. The relation between the amplitude of the video-frequency signal at the demodulator and the control voltage at the cathode-ray tube is discussed.

621.397.62.002.2 3377
**Adjustment Procedures for Color TV Production**—C. T. McClane. (*Electronics*, vol. 27, pp. 140–143; August, 1954.)

621.397.621 3378
**A Television Deflection Unit with Castellated Ferroxcube Cores**—[*Philips Tech. Commun. (Australia)*, no. 2, pp. 18–19; 1954.]

621.397.74:621.397.335 3379
**Pulse Distribution in TV Network Origination**—J. S. Auld and A. Gallonio. (*Electronics*, vol. 27, pp. 166–168; August, 1954.) Description of arrangements for use at a studio center for feeding synchronizing and blanking pulses to the various studios, projection rooms, monitoring and picture recording points.

621.397.743.029.63 3380
**Considerations relating to a Plan for a Television Transmitter Network for Band 4 (470–585 Mc/s) [in the Federal German Republic]**—K. Buchta. (*Frequenz*, vol. 8, pp. 137–143; May, 1954.) The need is emphasized for giving careful consideration to receiver design when planning the geographical and frequency distribution of the television transmitters. The choice of receiver IF is considered from the point of view of protection from oscillator radiation and other types of interference and the provision of high selectivity. Examination of the problem is based on previous proposals to use an IF of 38.9 mc for the picture and 33.4 mc for the sound. Single- and double-heterodyne receivers are considered, and cases of particular frequency relations are investigated. Some specific recommendations are tabulated.

621.397.8:535.735 3381
**Relationship between Critical Flicker-Frequency and a Set of Low-Frequency Characteristics of the Eye**—H. de Lange Dzn. (*Jour. Opt. Soc. Amer.*, vol. 44, pp. 380–389; May, 1954.) See also 1841 of 1953.

621.397.9 3382
**Moving-Target Detector**—J. L. McLucas and R. D. Laughlin. (*Electronics*, vol. 27, pp. 169–171; August, 1954.) A simple arrangement for observing moving objects at a remote location comprises an image dissector with rotating-mirror scanner and photocell pickup and a special cathode-ray tube viewing device on which the image is produced by a raster of vertical bars. A typical scanning rate is one raster per second; the bandwidth transmitted is much less than for ordinary industrial television. Applications include intruder detection and surveillance of assembly line.

## TRANSMISSION

621.396.61:621.372.512 3383
**Coupling Circuits for Transmitters**—A. Simon. (*Fernmeldetech. Z.*, vol. 7, pp. 241–246; May, 1954.) The frequency variations of the voltage ratio, the effective resistance and reactance of various untuned and tuned hf coupling circuits, including frequency-compensated *LCR* circuits, are calculated and the results are tabulated and presented graphically. The frequency-compensated circuits are suitable for wide-band coupling (e.g. 4–30 mc), but large change of the reactance with frequency may occur.

621.396.61:621.396.822.1 3384
**A Particular Case of Cross-Modulation in the Field of High-Power Transmitters**—G. Schellmann and K. Vogt. (*Fernmeldetech. Z.*, vol. 7, pp. 232–234; May, 1954.) Combination frequencies were observed at $f_1-f_2$, $2f_1-f_2$, $2f_1+f_2$, and higher frequencies, with the transmitter at Weisskirchen (Taunus) operating on a frequency $f_1=872$ kc and that at Heiligenstock on $f_2=593$ kc. The respective power outputs of the two transmitters were 150 kw and 100 kw; the distance between antennas was 9 km. The presence of the Weisskirchen modulation on the Heiligenstock carrier was also observed. Using direction-finding equipment operating at $2f_1-f_2$ the source of the cross-modulation was traced to the Weisskirchen

transmitter and found to be due to the high voltages picked up by the antenna and fed back to the wide-band Doherty-type output-stage anode load.

621.396.61.029.51+621.396.712 3385

**Very-High-Power Long-Wave Broadcasting Station**—Smith, Hall and Welden. (*See* 3357.)

621.396.61.029.55 3386

**Radio Transmitters in the American Cable and Radio System**—F. D. Webster. (*Trans. I.R.E.*, vol. CS-2, pp. 122–132; July, 1954.) Illustrated description of transmitters for telephone and telegraph point-to-point service at frequencies between 4 and 26 mc, one with 7.5 kw and the other with 30 kw output power.

## TUBES AND THERMIONICS

621.314.63+621.314.7]:621.311.6 3387

**Transistors and Junction Diodes in Telephone Power Plants**—F. H. Chase, B. H. Hamilton and D. H. Smith. (*Bell Syst. Tech. Jour.*, vol. 33, pp. 827–858; July, 1954.) Discussion indicates that semiconductor junction diodes and transistors have a wide field of application in power conversion and control. The dependence of the characteristics on temperature is a difficulty not yet entirely overcome; thermistors, nickel-wire resistors and suitable circuit arrangements can be used to provide temperature compensation. In most cases the regulating circuits described take their own power supply directly from the regulated output.

621.314.63.029.6 3388

**Negative Resistance arising from Transit Time in Semiconductor Diodes**—W. Shockley. (*Bell Syst. Tech. Jour.*, vol. 33, pp. 799–826; July, 1954.) Detailed examination of the production of negative resistance in semiconductor diodes is based on consideration of the "impulse impedance." The investigation is relevant to the design of "dissected amplifiers" [2901 of November (Shockley & Mason)] for operation at frequencies higher than those for which transistors are suitable. Particular structures discussed include (a) a "minority-carrier delay diode" comprising a *p-n-p* structure, in which both types of carrier are effective, and (b) a unipolar diode which is again a *p-n-p* structure, but in which only one type of carrier is effective. Theory developed by Krömer (2821 of 1953) is discussed; hole mobility may become negative at very high field strength. Negative resistance characteristics can also be achieved by a convergent configuration of the diode.

621.314.7 3389

**Theory of Diffusion-Type and Drift-Type Transistors: Part 1—The Quadripole Matrix for Low Frequencies**—H. Krömer. (*Arch. elekt. Übertragung*, vol. 8, pp. 223–228; May, 1954.) The quadripole matrix representation of a drift-type *p-n-p*-junction transistor (1605 of June) is developed. The four quadripole admittances are derived from the equations expressing the flow of holes through the base, taking account of the decrease of base thickness as the collector voltage rises. The ordinary diffusion-type transistor is included as a special case. As compared to the diffusion type, the drift type has a current amplification factor closer to unity, lower collector admittance, and lower feedback. The results are compared with those of Early (1244 of May).

621.314.7 3390

**Extension of the Theory of the Junction Transistor**—E. S. Rittner. (*Phys. Rev.*, vol. 94, pp. 1161–1171; June 1, 1954.) Examination of Shockley's theory (379 of 1950) shows that it is valid for the emitter and collector regions for all values of current, but for the base region only for extremely small current values. The theory for the base region is extended to apply to arbitrary injection level, and to take account of the effect of surface recombination. Surface recombination velocity should increase with injection level, and the $\alpha$ cutoff frequency at high injection level should be approximately twice that for very low injection level for transistors with plane-parallel junctions.

621.314.7:546.289 3391

**Developmental Germanium Power Transistors**—E. G. Roka, R. E. Buck and G. W. Reiland. (PROC. I.R.E., vol. 42, pp. 1247–1250; August, 1954.) An alloyed-junction transistor is described, capable of delivering several watts at temperatures from normal to 130 degrees F. It is sealed in a metal case, the collector being soldered directly to the bottom of the case and the base and emitter leads being brought out via glass/metal seals. A method of mounting the transistor on a chassis is shown which provides effective heat transfer. Maximum collector current is of the order of 1A and maximum collector voltage is 60 v. Collector *v/i* characteristics obtained at mounting-base temperatures of 75 degrees and 175 degrees F are shown.

621.314.7:621.373.52 3392

**Internal Transistor Oscillations**—H. E. Hollmann. (PROC. I.R.E., vol. 42, p. 1323; August, 1954.) See 2540 of September.

621.314.7:621.396.822 3393

**Note on Shot and Partition Noise in Junction Transistors**—A. van der Ziel. (*Jour. Appl. Phys.*, vol. 25, pp. 815–816; June, 1954.) Discrepancies between theoretical and experimental values of noise figure found by Montgomery and Clark (1248 of May) are removed by taking partition noise into account.

621.383.2(083.7) 3394

**I.R.E. Standards on Electron Devices: Definitions of Terms Related to Phototubes, 1954**—(PROC. I.R.E., vol. 42, pp. 1276–1277; August, 1954.) Standard 54 I.R.E. 7 S1.

621.385 3395

**Control-Grid Currents in Radio Receiving Valves**—E. Watkinson. [*Proc. IRE* (*Australia*), vol. 15, pp. 139–143; June, 1954.] "The effects of 'contact potential' on the operating conditions of a tube and its circuit are described, with particular reference to the operation of battery tubes under zero-bias or 'grid-leak bias' conditions. Reverse grid currents, their causes and effects are also discussed and precautions that may be taken to minimize variations of tube operating conditions by these currents are given."

621.385.002.2 3396

**Foreign Tube Design Techniques**—T. H. Briggs and F. R. Michael. (*Tele-Tech*, vol. 13, pp. 58–60, 104; July, 1954.) Tube manufacturing techniques used in Europe are analysed from the point of view of possible improvements in U.S. methods.

621.385.004.15 3397

**A Study of Some of the Properties of Materials affecting Valve Reliability**—E. A. O'D. Roberts. (*Proc. IEE*, part III, vol. 101, pp. 197–205; July, 1954. Discussion, pp. 205–209.) The mechanism of fracture in glass envelopes is briefly analysed and empirical relations are established between the probability of fracture and tube age, both for normal and for special-quality tubes. A similar analysis for fractures at welded metal joints yields similar results. The concept of safe amplitude of stress or strain under vibration is applied to study fatigue fractures in metal components and in mica spacers, and the design and manufacturing features which determine the most dangerous stress amplitudes are explained. Improvements in the manufacturing process to minimize fractures of all types are described.

621.385.029.6 3398

**A New Electron Tube: the Strophotron**—H. Alfvén and D. Romell. (PROC. I.R.E., vol. 42, pp. 1239–1241; August, 1954.) An experimental transit-time tube is described, the operation of which combines density modulation of the electron beam with control of the electron drift velocity in a direction perpendicular to the oscillatory motion, electrons being withdrawn from the rf field at an instant favourable from the efficiency point of view. The desired electron motion is produced by crossed electric and magnetic fields, as in the trochotron. The tube has a frequency range of about an octave without mechanical tuning.

621.385.029.6 3399

**The Helix as a Backward-Wave Circuit Structure**—D. A. Watkins and E. A. Ash. (*Jour. Appl. Phys.*, vol. 25, pp. 782–790; June, 1954.) The impedance of the retarding helix is an important factor in the design of backward-wave oscillators. Curves are derived showing approximately the variation of the impedance with the ratio of circumference to free-space wavelength, for single and bifilar helixes. It is shown that if in two tape helixes the gap width of one is equal to the tape width of the other, their backward-wave impedances are equal.

621.385.029.6 3400

**Study of the Static Properties of Magnetron-Type Space Charges**—J. L. Delcroix. [*Ann. Phys.* (*Paris*), vol. 9, pp. 269–321; May/June, 1954.] A detailed theoretical study is made for magnetrons of various configurations, particularly coaxial-cylinder types, both plain and inverted, with axial and circular magnetic fields. Experiments are described which demonstrate the transitions between the different states. A Brillouin regime is found to exist for all the types considered, while the existence and number of the bidromic regimes depend on the particular type of magnetron. See also 1210 of 1953 and back references.

621.385.029.6:538.691 3401

**Relativistic Dynamics of a Charged Particle in Crossed Magnetic and Electric Fields with Application to the Planar Magnetron**—L. Gold. (*Jour. Appl. Phys.*, vol. 25, pp. 683–690; June, 1954.) Analysis is restricted to electron energies of moderate relativistic values such that radiation loss is negligible. The cutoff voltage is found to vary linearly with the product of electrode separation *L* and magnetic field *H*, rather than quadratically as in the nonrelativistic case. The quasicycloidal period is found to depend on the voltage. The main formulas derived are listed.

621.385.029.63/.64:621.396.822:621.372.2 3402

**A Minimum Noise Figure for the Traveling-Wave Tube**—S. Bloom and R. W. Peter. (*RCA Rev.*, vol. 15, pp. 252–267; June, 1954.) A general expression is derived for the minimum obtainable noise figure, making use of the transmission-line-analog theory previously developed (2810 of October) and assuming arbitrary values of space charge and helix loss. Design formulas are presented for realizing this minimum figure. Impedance diagrams commonly used in transmission-line problems can be adapted to simplify the design of an optimum impedance transformation along the beam in a low-noise gun.

621.385.029.64:[621.376.22+621.376.32 3403

**723 A/B Reflex Klystron Performance**—Zito. (*See* 3180.)

621.385.032 3404

**Ceramic Tube Mount for Automatic Assembly**—R. N. Palmer. (*Electronics*, vol. 27, pp. 162–165; August, 1954.) Details are shown of a construction for receiving tubes in which mica insulators are eliminated. Elements are stacked on two vertical pins and located by ceramic spacers, and the assembly is mounted on a flat ceramic stem and enclosed in a ceramic or glass envelope. Frame grids are used. For another account see *Tele-Tech*, vol. 13, pp. 69, 156–157; August, 1954.

621.385.032.213.2 3405

**New Method of Measuring the Cathode Temperature of Indirectly Heated Vacuum Tubes**—S. Ikehara. (*Jour. Appl. Phys.*, vol. 25, pp. 725–732; June, 1954.) A method is described which makes use of the high harmonic component present in the initial current flowing to the anode, with alternating voltage applied to the anode. The method is rapid and reliable and gives a direct temperature reading. Results for diode, triode and pentode tubes are compared with values obtained by other methods.

621.385.032.216 3406

**Reactions between Oxide Cathodes and Gases at Very Low Pressures**—S. Wagener. (*Proc. Phys. Soc.*, vol. 67, pp. 369–386; May 1, 1954.) The experimental tube used has a lower tetrode part and an upper ionization-gauge part which is operated by space-charge-limited emission, the gauge thus indicating the pressure directly in front of the cathode. The thermionic emissivity is simultaneously measured by drawing a pulsed emission current from the cathode. The gases investigated were $O_2$, $CO_2$, CO, $N_2$, water vapor, $H_2$ and $CH_4$, over the pressure range $10^{-7}-10^{-5}$ mm Hg. Poisoning of emission by $O_2$ increases with increasing pressure and decreases with rise in temperature. It is independent of core material, and seems to be due to neutral particles and not to ions. From the rate of flow of $O_2$ into the cathode the quantity of Ba consumed during poisoning is estimated as of the order of 0.01 mol per cent. After exposure to $O_2$ cathode recovery is complete for temperatures between 1,000 degrees and 1,100 degrees K but not for those above 1,200 degrees K. At pressures below $5\times10^{-6}$ mm Hg poisoning by $CO_2$ is more pronounced for cathodes with Pt cores. CO poisons cathodes with Ni cores, but activates those with Pt cores. $N_2$ does not affect emission appreciably; water vapor, $H_2$ and $CH_4$ activate at pressures below $10^{-5}$ mm Hg. The existence of a critical pressure for activation by $CH_4$ was demonstrated.

621.385.032.216 3407

**Oxide Cathodes in Accelerating Fields**—P. N. Daykin and D. A. Wright. (*Proc. Phys. Soc.*, vol. 67, pp. 439–441; May 1, 1954.) In the theoretical treatment of emission in an accelerating field [2662 of 1952 (Woods and Wright)] (2) is not accurate and a limit is thus imposed on values of $J/\sigma$ for which the given solution is satisfactory. A more general treatment by Shindo [2082 of 1952 and 591 of March] is recommended. See also 2819 of October (Shindo).

621.385.032.216 3408

**Some Measurements of the Electrical Conductivity, Thermoelectric Power and Other Properties of the Coating in the Oxide-Coated Cathode**—C. M. Lovett. (*Proc. Phys. Soc.*, vol. 67, pp. 387–394; May 1, 1954.) Measurements of the conductivity of cathodes coated with Ba-Sr oxide were carried out under carefully controlled conditions over the temperature range 700 degrees–900 degrees K. Results showed that only one work function exists. This was confirmed by thermoelectric-power measurements.

621.385.032.216 3409

**On the Conductivity of Oxide Cathode Coatings**—T. B. Tomlinson. (*Jour. Appl. Phys.*, vol. 25, pp. 720–724; June, 1954.) Conduction through the oxide coating was investigated experimentally by measuring the resistance between the cathode core and a helical metal probe embedded in the coating. *I/V* characteristics of diodes with such probes, for temperatures above 700 degrees K, are generally linear at high positive and negative potentials but curved at lower potentials. A modified form of the Loosjes-Vink two-mechanism conduction theory (3208 of 1950) is presented which fits the experimental results and according to which the system can be represented by an equivalent circuit comprising a diode with a series resistance all in parallel with a larger resistance.

621.385.032.24.002.2 3410

**An Electron-Tube Frame Grid Adaptable to Automatic Production**—R. E. Booth and R. C. White. (*Sylvania Tech.* vol. 7, pp. 58–60; April, 1954.) The dimensions of the grid described can be controlled with great accuracy because the lateral wires are brazed to the frame. The construction is rugged, and wire diameters as low as 0.00034 inch have been used successfully.

621.385.032.44:621.397.62 3411

**Service Heater Strings for TV Receivers**—Roberts. (*See* 3374.)

621.385.2/.3:621.396.822 3412

**Tube Noise under Large-Transit-Time Conditions**—S. V. Yadavalli. (*Jour. Appl. Phys.*, vol. 25, pp. 564–568; May, 1954.) The influence of transit time on shot noise in diodes is studied by the Rack-Llewellyn-Peterson method [2578 of 1944 (Llewellyn and Peterson)]; the results are applicable to triodes under certain conditions. Comparison of theoretical and experimental results indicates that under small-signal conditions the thermal distribution of electron velocities can safely be neglected.

621.385.3 3413

**The Amplification Factor of a Triode: Part 3—Supplement**—M. Wada. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, vol. 5, pp. 87–95; June, 1953.) Simplified equations for calculating the amplification factor of planar and cylindrical triodes and corrections to previous parts (552 and 3607 of 1952) are given.

621.385.3/.4:621.396.822 3414

**The Limiting Sensitivity of Amplifier Valves: Part 3—Equivalent Noise Conductance and Noise Figure**—H. Rothe. (*Arch. elekt. Übertragung*, vol. 8, pp. 201–212; May, 1954.) Theory given in the preceding papers is summarized, and modified nomenclature is introduced. From the general expression for the equivalent noise current at the grid an equivalent noise conductance is derived; this is a characteristic parameter which can easily be determined experimentally. From this noise conductance, together with the usual noise resistance and the input conductance of the tube and the parameters of the input circuit, the properties of the amplifier stage can be determined as regards both circuit operation and noise. An examination is made of the correlation between noise entering from the anode and that from the grid, and the dependence of the noise power on this correlation is discussed. The behavior, in respect of matching and noise factor, of a tube with given parameters in an input stage is investigated. Part 2: 1538 of 1953 (Rothe and Willwacher).

621.385.3/.4].002 3415

**Mechanical Problems of Electron Tubes for L3 Carrier**—E. J. Walsh. (*Bell Lab. Rec.*, vol. 32, pp. 183–187; May, 1954.) Details of construction and manufacture of tubes Type 435A, 436A and 437A [1165 of 1952 (Ford and Walsh)], including an outline of optical techniques for checking grid-wire tension and mica insulators.

621.385.3/.4].029.62 3416

**Radiation-Cooled Transmitting Triodes and Tetrodes for High Frequencies**—R. Hübner. (*Brown Boveri Rev.*, vol. 40, pp. 495–501; November/December, 1953.) Discussion of construction and applications of triodes T130-1 and T350-1 and tetrodes Q160-1 and Q400-1 for outputs up to 1 kw and frequencies up to 220 mc.

621.385.5:621.397.62 3417

**Valves for use in Band III Television Tuners**—L. Hampson and P. D. Neville. (*Mullard Tech. Commun.*, vol. 1, pp. 161–172; May, 1954.) The characteristics are described of the Type-PCC84 double-triode and Type-PCF80 triode-pentode tubes which have been designed for use in the front-end stages of television receivers working on either Band I or Band III. Both are in the B9A all-glass miniature range. Performance in a practical circuit is discussed.

621.385.832 3418

**The Metrechon—A Halftone-Picture Storage Tube**—L. Pensak. (*RCA Rev.*, vol. 15, pp. 145–162; June, 1954.) The composite target of this tube comprises a fine metal mesh in contact with a thin sheet of insulator; it is scanned on one side by a high-velocity writing beam and on the other side by a low-velocity reading beam. The collector surrounds the reading gun. Four modes of operation corresponding to different ranges of target-mesh potential are discussed. The stored pattern can be read thousands of times without deterioration. The tube was developed primarily for processing radar PPI patterns; other possible applications are mentioned.

621.385.832 3419

**Skiatrons**—K. H. J. Rottgardt. (*Fernmeldetech. Z.*, vol. 7, pp. 249–253; May, 1954.) A brief account is given of the operation and construction of several skiatron-type tubes developed during the war in Great Britain, the U.S.A. and Germany. A tube is also described in which the screen is observed from the same side as the incident electron beam and the illumination; higher picture-contrast is claimed for this type of construction.

621.385.832:535.37 3420

**Destruction of Luminescence of Cathode-Ray-Tube Screens by Electrons**—K. H. J. Rottgardt. (*Z. angew. Phys.*, vol. 6, pp. 160–163; April, 1954.) The decrease in luminescence due to electron bombardment, investigated for $Zn_2SiO_4$:Mn, ZnS:Ag, and CdS:Cu screens, shows a marked dependence on vacuum conditions. In CdS:Cu screens having a uniform particle size, the degree of electron burn depends on the number of incident electrons and is independent of the beam current and anode voltage up to 4 kv. Electron and ion burns can be removed by heating at 400 degrees C. for ½ hour and restoring the tube vacuum. It is suggested that lattice defects are produced by ionization by the bombarding electrons; these defects constitute deep traps in the band structure of crystal phosphors via which radiationless transitions may take place.

621.385.832:537.56 3421

**The Negative-Ion Components of the Electron Beam in Cathode-Ray Tubes, particularly Television Tubes**—W. F. Niklas. (*Philips Res. Rep.*, vol. 9, pp. 122–130; April, 1954. In German.) The source and the nature of the negative-ion component were found by means of a mass-spectrometer-type method. The cathode ions were identified as $Cl^{35}$, $Cl^{37}$ and CN or $C_2H_2$; the ions produced in the gas between the grid and first anode were O, CH and C. A reduction in the residual gas pressure resulted in the elimination of the latter group; the occurrence of CN (or $C_2H_2$) ions decreased with time. An account of the experimental method is given.

621.387 3422

**Effects of Ambient-Temperature Variations**

**on Glow-Discharge Tube Characteristics**—F. A. Benson and G. Mayo. (*Jour. Sci. Instr.*, vol. 31, pp. 118–120; April, 1954.) Measurements on ten different types of tube are reported; typical temperature/running-voltage curves are shown. Large variations in the shapes of the characteristics may occur in tubes of a given type, and the gas filling seems to be an important factor in determining the sign of the temperature coefficient. Some tubes exhibit a change of sign of temperature coefficient.

621.387:621.318.572 3423

**Measurements of the Gas Temperature of a Low-Pressure R.F. Discharge**—I. Reingold and K. Garoff. (*Jour. Appl. Phys.*, vol. 25, pp. 537–540; April, 1954.) Measurements were made of the temperature of ionized gases at low pressure in atr cavities having windows of different *Q* values, the discharge being initiated by a high-power pulse at 2.82 kmc. $N_2$, $H_2$, Ar, and Ar and water vapor were studied. From the point of view of heat dissipation, Ar is the most effective filling and, of the single-iris windows, those with higher *Q* give the better performance at high power levels. A double-iris window combining good mechanical strength with reasonably low *Q* can operate at higher power levels and dissipate more heat than comparable cavities with single-iris windows.

621.387.032.5 3424

**Gas Tube Filament Connections**—M. Brenner and H. G. Schmitt. (*Trans. AIEE*, part I, *Communication and Electronics*, vol. 72, pp. 776–784; 1953. Discussion, pp. 784–785.) Measurements indicate that the flexible lead connection is preferable to the pin-and-socket connection from the point of view of cool running.

621.314.63+621.314.7 3425

**Kristalloden-Technik. (Book Review)**—R. Rost. Publishers: W. Ernest & Sohn, Berlin, 1954, 185 pp., DM 13.50. (*Arch. elekt. Übertragung*, vol. 8, p. 154; April, 1954.) Describes the preparation, characteristics, methods of testing and applications of crystal diodes and transistors.

## MISCELLANEOUS

061.4:621.3 3426

**French Components Show, 1954**—E. Aisberg. (*Wireless World*, vol. 60, pp. 287–289; June, 1954.) Main trends at the Salon de la Pièce Détachée are outlined. For more detailed accounts in French, see *TSF et TV*, vol. 30, pp. 154–159, 187–192 and 221–228; April–June, 1954. *Télévision*, pp. 132–136; May, 1954. *Rev. Son*, pp. 114–116; April, 1954.)

061.4:621.39 3427

**Report of the German Industries Fair, Hanover**—[*Funk-Technik* (*Berlin*), vol. 9, pp. 262–267; May, 1954.] Radio and television receivers, usw and television antennas, and interference-suppression arrangements shown at the 1954 exhibition are described. See also *Z. Ver. Dtsch Ing.*, vol. 96, pp. 631–638; July 1, 1954.

621.3.012 3428

**New Electronic Drafting Tools and Techniques**—J. R. McDermott. (*Electronics*, vol. 27, pp. 121–125; August, 1954.) Aids described for preparing circuit and wiring diagrams include rubber stamps, stencils, pre-prepared lettering on adhesives, etc.

621.39.001.891 3429

**Facilities for Experimental Work in the Engineering Department**—W. West. (*P.O. Elect. Eng. Jour.*, vol. 47, part 1, pp. 10–14; April, 1954.) Brief accounts of the research and development work undertaken in the various branches of the Engineering Department of the British Post Office, particularly in the communications field. The work at the main research station at Dollis Hill was described earlier (e.g. 1486 of 1952).

621.39.001.891:538.56.029.6 3430

**Centre for the Study of Microwave Physics [Florence]. Activities during the Year 1952 in Collaboration with the Military Geographical Institute**—N. Carrara. (*Ricerca Sci.*, vol. 24, pp. 987–991; May, 1954.) The subjects studied included the use of radar for geodesy and for investigating atmospheric precipitation, the propagation of em waves through fogs, and the design of vhf transmitter-receivers.

621.396.6 3431

**Soviet Radio Equipment at the Foire de Lyon**—(*TSF et TV*, vol. 30, pp. 217–218; June, 1954.) Radio and television receivers, measuring instruments, antennas, etc., were among the equipment on show at the 1954 exhibition.

621.396.6.002.2 3432

**Manufacturing Cost Determination of an Automatic Electronic Factory**—(*Tech. News. Bull. Nat. Bur. Stand.*, vol. 38, pp. 77–79; May, 1954.) Report of an analysis indicating the manufacturing economies consequent on the use of modular design and mechanized production [693 of March (Henry and Rayburn)].

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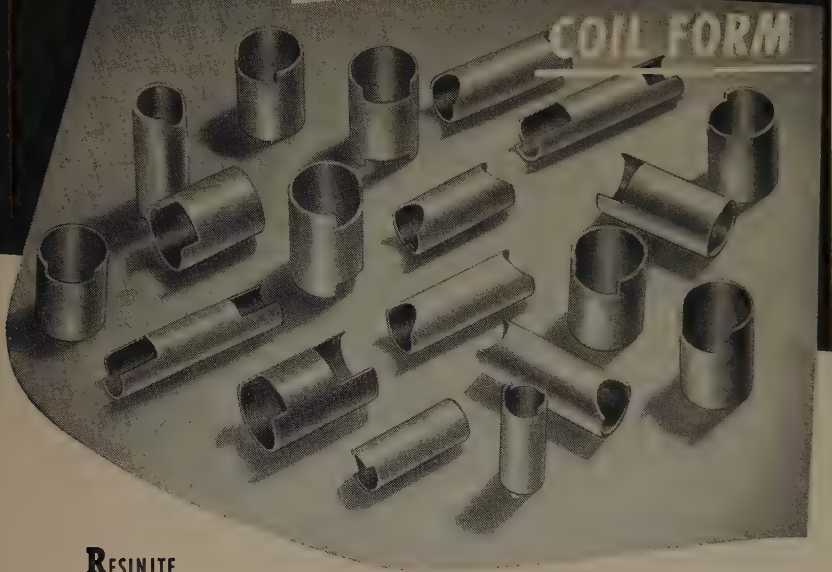

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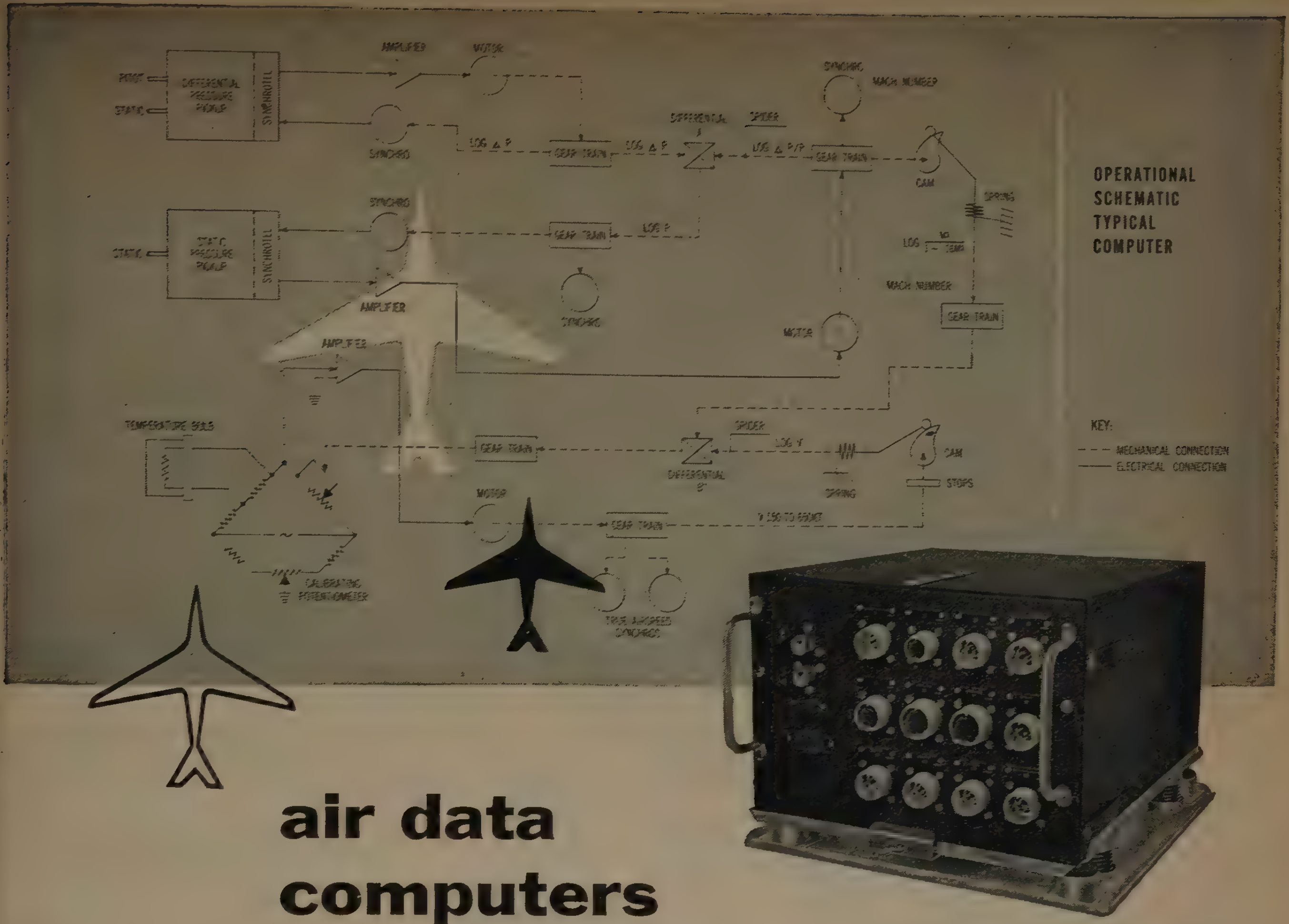
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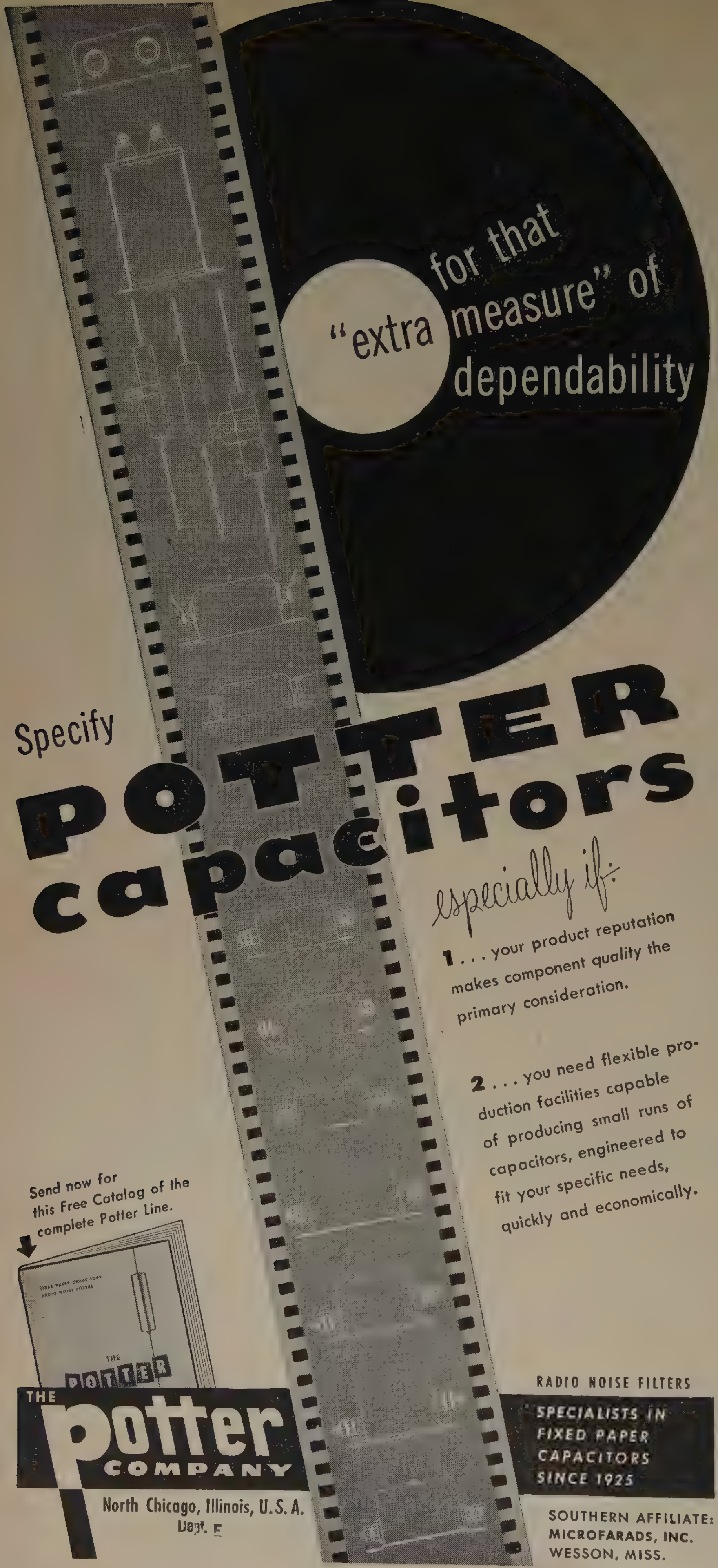

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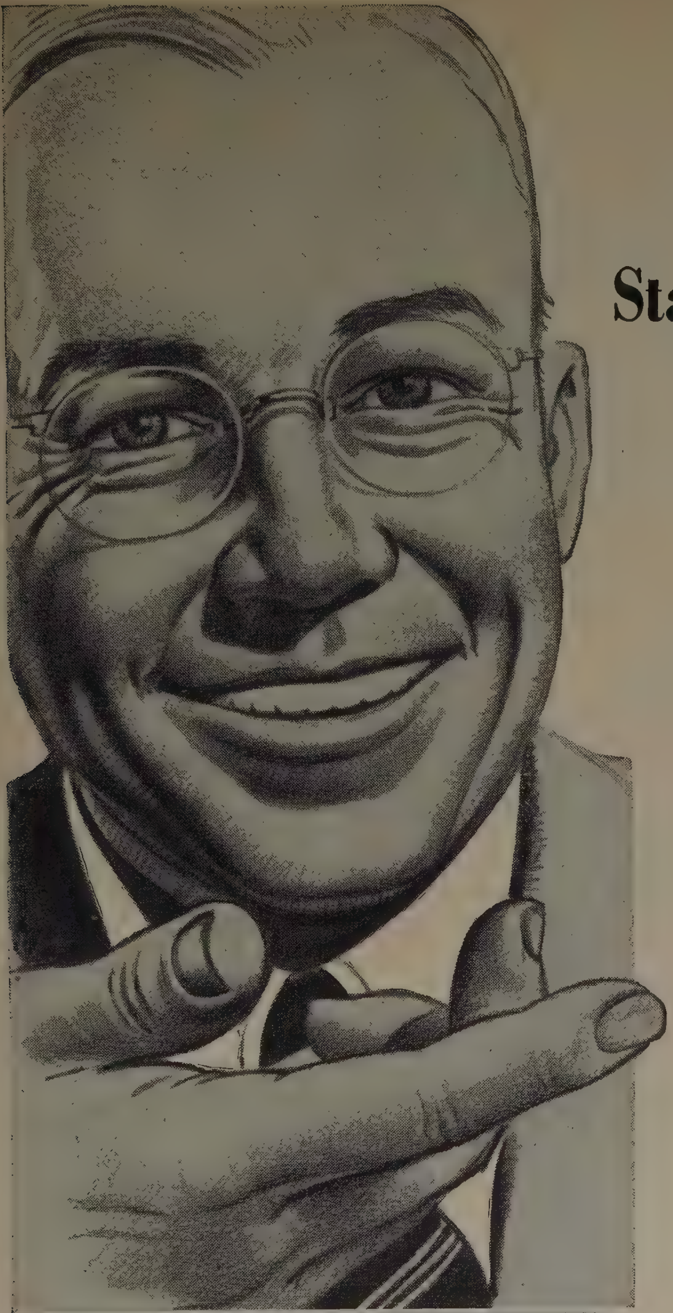

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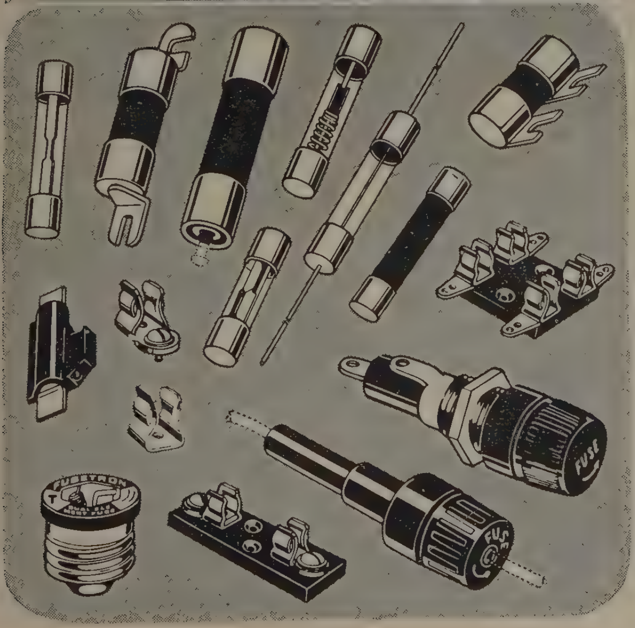

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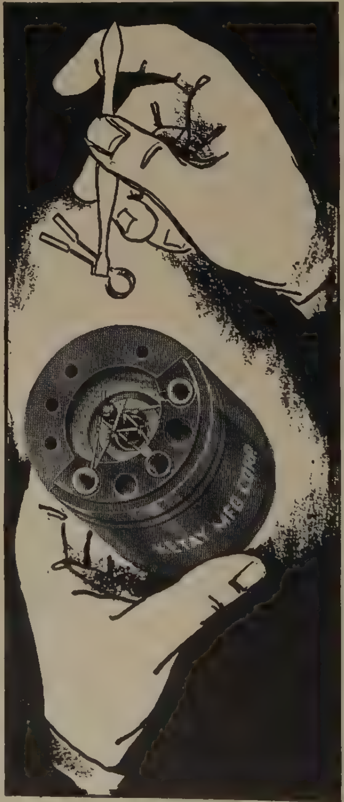

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(Continued on page 90A)

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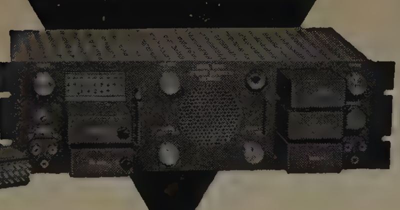
(*Continued on page 92A*)

# PIPELINE TO PRECISION



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**FREQUENCIES**—Choice of three RF front ends delivered with receiver, 2.5, 5, 10, 15, 20 or 25 mc.

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**50 watts to 400 mc**
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**10 watts to 2500 mc**

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A NEW INSTRUMENT of unusual capabilities, the Maxson Model M1141 UHF Wideband Power Oscillator, provides exceptionally broad frequency coverage and substantial power output in a single source. A simple changeover of feedback assemblies provides overlapping coverage of the full range in two bands. For easier portability, the instrument is divided into two units. Provision is made for internal and external amplitude modulation and for CW operation. With its smooth tuning and precise resettability, the Model M1141 is an excellent general-purpose signal source.

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- Internal sine-wave 1000 cps
- External

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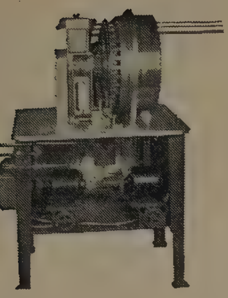

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*(Continued on page 94A)*

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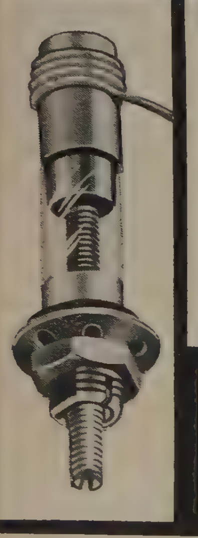

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AIR EXPRESS DELIVERY ON STANDARD MODELS

| MODEL | CAP. MMF | TEMP. COEFF. PPM PER °C | DIEL. | ROTOR ELECTRODE | TEMP. RANGE |
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| VC 5 | .5 to 5 | approx. zero | Quartz | Invar | −55°C to +200°C |
| VC 11 | 1 to 10 | approx. zero | Quartz | Invar | −55°C to +200°C |
| VC 12 | 10 to 20 | approx. zero | Quartz | Invar | −55°C to +200°C |
| VC 1G | .5 to 8 | +50 ± 100 | Glass | Invar | −55°C to +125°C |
| VC 3G | .7 to 8 | +600 ± 100 | Glass | Brass | −55°C to +125°C |
| VC 4G | 1 to 18 | +600 ± 100 | Glass | Brass | −55°C to +125°C |
| VC 11G | .7 to 12 | +100 ± 50 | Glass | Invar | −55°C to +125°C |
| VC 11GRB | .7 to 10 | +750 ± 100 | Glass | Brass | −55°C to +125°C |
| VC 11GRC | .7 to 10 | +275 ± 100 | Glass | Invar<br>Brass Screw | −55°C to +125°C |
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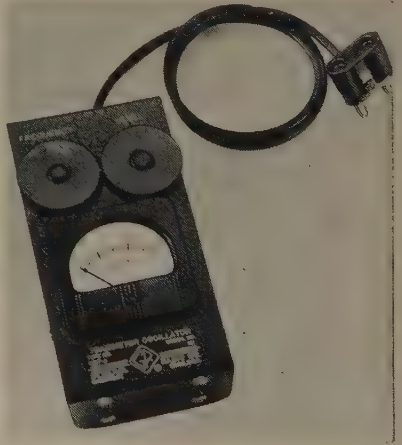
## News-New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

*(Continued from page 14A)*

### Transistor Oscillator For AF Testing

The first instrument resulting from a development program in transistor circuits and applications is announced by **General Radio Co.**, 275 Massachusetts Ave., Cambridge 39, Mass., as the Type 1307-A Transistor Oscillator. Completely self-contained, including batteries and output meter, the oscillator is also small enough to be held easily in one hand. Two frequencies, 400 and 1,000 cps are available with a maximum output of at least 2 volts across a 600-ohm load. The output voltage is adjustable and is read on the meter.

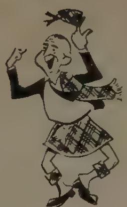


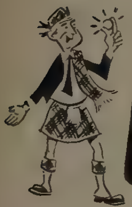
The oscillator is useful in checking the sensitivity of oscillographs and other instruments, making calibration voltage to the Type 1552-A sound-level calibrator for standardizing sound-measuring equipment.

The type 1307-A Transistor Oscillator uses a P-N-P junction transistor in a Hartley oscillator circuit. Price $88.00 f.o.b. Cambridge.

*(Continued on page 96A)*

# MORE FOR YOUR POWER SUPPLY DOLLAR





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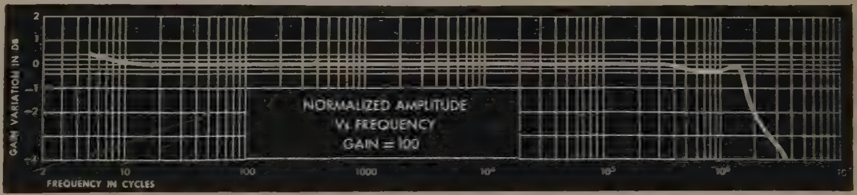
Featured by its wide band response, high input impedance, low output impedance, and compact dimensions, TIC's Type 500-A wide band decade amplifier is excellent as a general purpose laboratory instrument. Here is an instrument for special applications requiring a zero phase shift and high stability of gain. TIC increases the general utility of this amplifier by including a self-contained power supply and cabinet or rack mounting.

### SPECIFICATIONS:

**Amplification:** 10, 100 and 1000 times, selected by 3-position rotary switch.

**Frequency Response:** Flat to ± .5 db from 5 cycles to 2 mc on gain of 10; Flat to ± .5 db from 5 cycles to 1.5 mc on gain of 100; Flat to ± .8 db from 5 cycles to 1 mc on gain of 1000.



**Amplification Accuracy:** ± 2% of nominal — dependent on precision resistors only; Unaffected by normal tube characteristics or line variations.

**Phase Shift on All Ranges:** 0 to ± 2° from 20 cycles through 100 kc

**Gain Stability on All Ranges:** Constant with line voltages of 105 to 124 volts.

**Noise and Hum:** 60 db below maximum output voltage with input shorted.

**Input Impedance:** Approximately 160 megohms shunted by 7 $\mu\mu f$.

**Output Impedance:** Approximately 200 ohms.

**Output Voltage on All Ranges:** 20 volts maximum output across a load of 20 k$\Omega$ or greater.

**Power Supply:** 105-125 volts, 50-60 cycles self-contained power supply requiring approx. 30 watts. (230 volt, 50-60 cycles models available).

**Mounting Dimensions:** Single, in cabinet: 13¼" wide x 5" high x 9⅜" deep. (11¼" x 3½" panel) Single, for rack: 19" wide x 3½" high x 8½" deep.

The low distortion is a feature much desired in amplifiers of this type.

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Albuquerque, N.M.— Albuquerque 3-1998
Chicago, Ill. — Uptown 8-1141

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**Linearity Beyond 0.01%**
*with*
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**Precision DEKAPOTS**

Shown: MODEL DP-211

*Additional Features*

**Resolution:** to better than 0.002%.
**Frequency Response:** less than 1° phase shift at 10 kc.
**Easy-Reading Dekadial:** all figures in horizontal line; read directly to four places.
**Exceptional Scale Length:** equals 100-turn potentiometer.
**Rapid Settings:** any reading within three turns.
**Convenient Installation:** mounts in single panel hole.
**Small Size:** 3″ diameter; 3½″ to 6″ deep.

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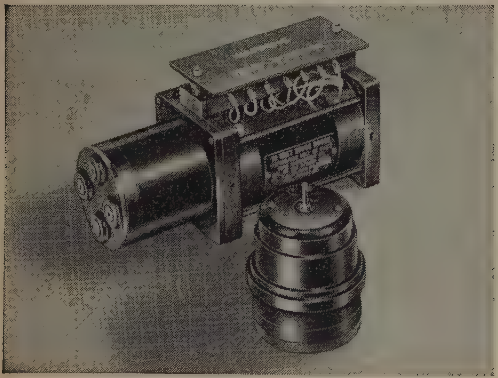
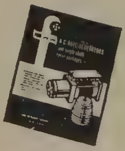
*Nationwide Representation*





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**PRECISION**
**A-C Rate Generators**
*and*
**single-shaft servo packages**

- offered in 60cy and 400cy models
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- available temperature compensated for wide ambient range

These a-c rate generators are designed for any use which requires a high degree of accuracy in the linear translation of rotational motion into voltage. They are especially valuable in servo systems to stabilize responses, and can be provided in convenient single-shaft packages with a wide variety of precision servo motors.

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33

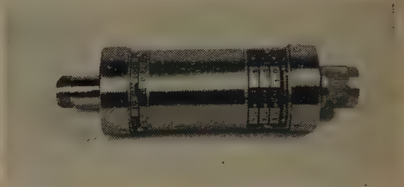
## News-New Products

**These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.**

*(Continued from page 94A)*

### Microwave Power Pad

**Weinschel Engineering Co., Inc.** 10503 Metropolitan Ave., Kensington, Md., has developed a new coaxial pad designed for a 10 watt input. Their power sensitivity is below 0.001 db per watt; that is, a 10 watt input to a 10 db pad changes the insertion loss less than 0.1 db.



The 3 and 10 db pads are within ±0.1 db of nominal between dc and 1,000 Mc. A calibration, accurate to 0.05 db, is furnished for 400, 750, and 1,000 Mc and to 0.02 db at dc. The long-term stability of these precision pads is commensurate with the accuracy of calibration. Price of a single unit is $150.

### Diode Clips

A new addition to its Series X2090 improved diode clips is announced by the **Cambridge Thermionic Corp.**, 445 Concord Ave., Cambridge, Mass. The new clips, designed for printed circuitry use, are designated as Series X2090-D. The chief difference between them and previously introduced clips in this series is in their base, which is single "spade" for force-fit into a 0.102 inch diameter hole. They stand ⅜ inch high when mounted. Type X2090C, also for printed circuit use, is similar to X2090D, but has a rivet-type mounting.

Like the other Series X2090 clips, the new D type is designed for diodes having nominal pin diameters of 0.079 inch but will accommodate 0.069 inch to 0.085 inch diameters.

The material is beryllium copper, alloy #25, heat treated after forming. Finishes are wither 0.0002 inch brite alloy or 0.0002 inch silver plus gold flash.

*(Continued on page 98A)*

thirty times as sensitive yet drift-free

THE OFFNER DYNOGRAPH

0.001 volt input d-c gives 70 mm. deflection with this high-speed direct writing oscillograph, as compared to only 2 mm. with the most sensitive competitive unit—and with zero drift.

The Dynograph with *one amplifier* is used for all types of inputs—d-c, a-c, or reluctance gauges for measuring speed, temperature, position, vibration, and other variables. Exclusive, patented, chopper amplifier design makes it sensitive, stable, and versatile—greatly increasing the scope of direct writing oscillographs.

*Get bulletin L742—compare the Dynograph with all competitive models—it's thirty times as sensitive.*

**OFFNER ELECTRONICS INC.**
5328 N. Kedzie Avenue
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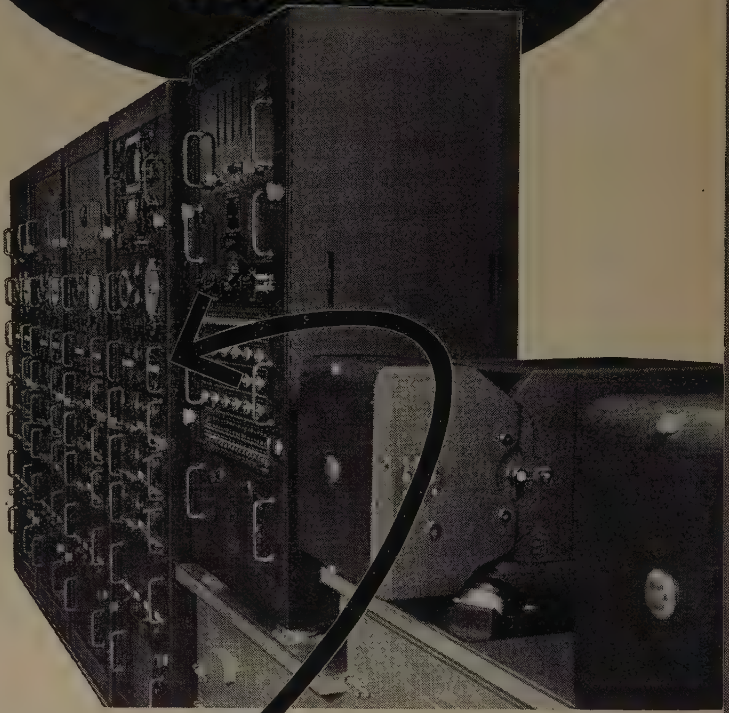
Bendix-Pacific
TELEMETERING RECEIVING STATIONS



NEW IMPROVED
**DISCRIMINATORS**
FOR

- GREATER ACCURACY
- INCREASED STABILITY
- BETTER LINEARITY
- ADJUSTABLE FREQUENCY RESPONSE
- HIGHER OUTPUT

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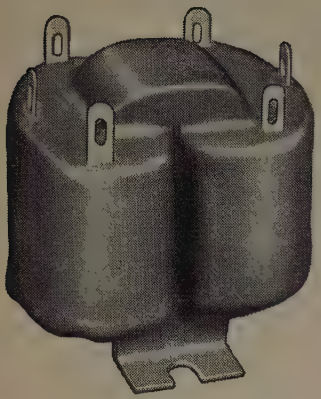
Pacific Division
Bendix Aviation Corporation
NORTH HOLLYWOOD, CALIF.

PLASTIC
ENCAPSULATED
TRANSFORMERS



To meet the need for transformers finished in any one of several tested plastic formulations, Acme Electric have complete production facilities as well as experienced personnel and supervisory engineers to produce this class of equipment.

*We invite your inquiries with specifications.*

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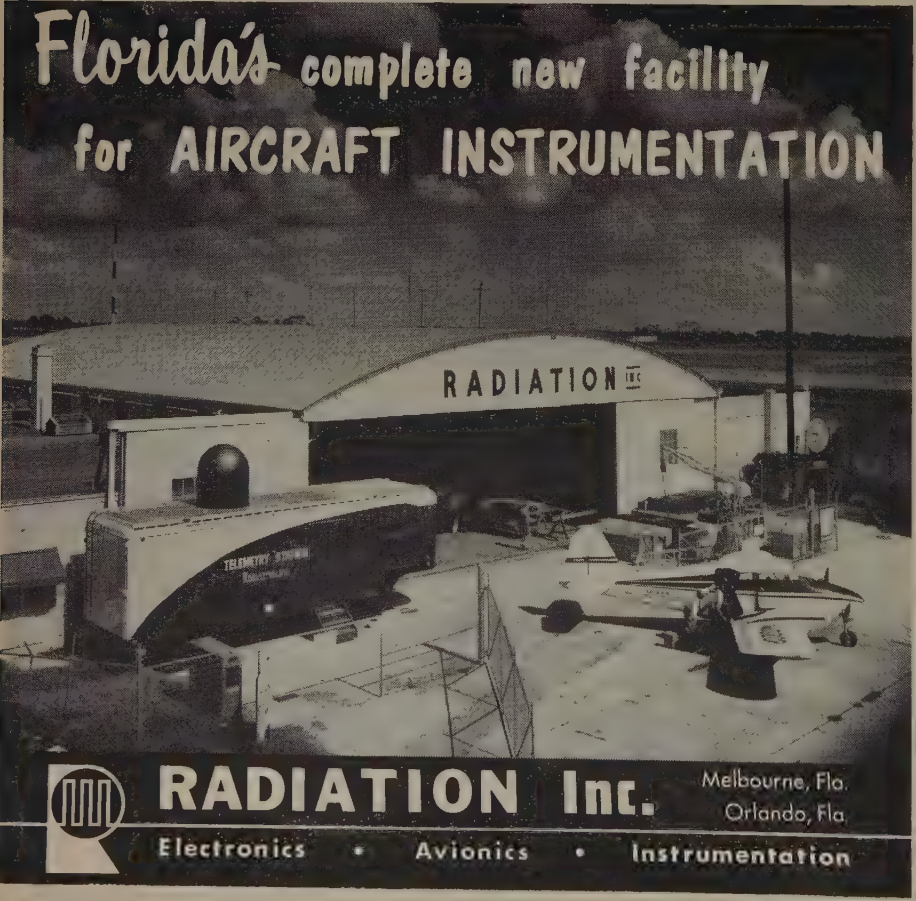
Acme ACME Electric
TRANSFORMERS



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for AIRCRAFT INSTRUMENTATION

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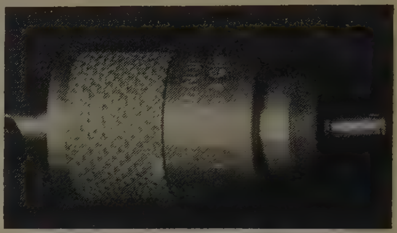
Electronics • Avionics • Instrumentation

## News-New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

*(Continued from page 96A)*

### Coaxial Termination Test Plug



**Holland Electronics**, 572 Broome St., New York 13, N. Y., has developed a new unit with integral test terminal which provides the comparability and accuracy necessary in testing amplifier gain and level in color TV systems, and eliminates undesired reflections and temporary expedients. It is claimed to represent also a substantial improvement in testing monochrome TV and other medium- and high-frequency circuits.

This single unit features a precision film-type resistor and an accessible test terminal. Type No. 259-75 includes a Type PL-259 plug with 75 ohm resistor, and is tested to 1 per cent tolerance before shipment. Other tolerances, resistance values, and plug types are available.

*(Continued on page 101A)*

PYRAMID

❶ Glasseal hermetically sealed sub-miniature paper tubulars. Manufactured to the highest commercial standards and engineered to the exacting performance requirements of Military Specification MIL-C-25-A.

❷ Oil paper capacitors of finest possible commercial quality, meeting MIL-C-25A and Jan-C-25 standards of precision.

❸ Electrolytics of superior commercial performance characteristics, meeting Jan-C-62.

*Write for Catalog J-8 for further detailed information. Or call your local Pyramid Sales Representative or write to:*

**PYRAMID ELECTRIC COMPANY**
Dept. 123, 1445 North Hudson Blvd., North Bergen, New Jersey

*Burton browne advertising*

(Continued from page 98A)

## Delay Line

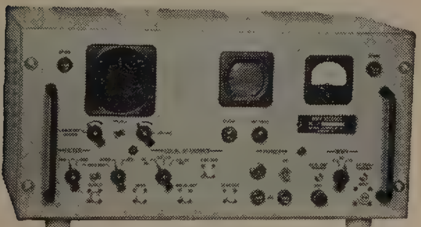
A new miniaturized unit delay-line (Model GVDL-1000-0.5) developed by **The Gudeman Co., of California, Inc.,** 9200 Exposition Blvd., Los Angeles 34, Calif., provides continuously variable delays from 0 to 0.5 microseconds. It features light weight, small size (¾ by 1⅛ by 7½ inches), fast rise time (0.075 microsecond at full delay), characteristic impedance of 1000 ohms, negligible attenuation, band width at full delay: 5 mc, and resolution of 0.0003.

The unit is designed to meet military requirements and will withstand normal shock and vibration without affecting the delay setting or calibration. It is designed for use in the laboratory, for radar, loran and airborne electronic systems, for establishing coincidence of sweep and input signals in high speed oscilloscopes, and measuring time intervals with an accuracy better than 1 milli-microsecond. Custom units with delays ranging from 0.1 to 1 microsecond and characteristic impedances of 500, 1000, and 1500 ohms are available. Data sheet may be obtained from the company.

(Continued on page 102A)

WWV IS FREE

Why Not Use It?



The WWV frequency standard, as transmitted by the U.S. Bureau of Standards, is the most accurate frequency standard of any in the world.

By using the new Matawan WWV receiver, this frequency standard, with all its information (standard audio frequencies, time signals, propagation notices) is now available to your laboratory. The WWV carrier, after elimination of its modulation, by means of a narrow band pass crystal filter, monitors your local HF standard. The rotative pattern on the screen of the cathode tube gives sense and direction of the frequency deviation.

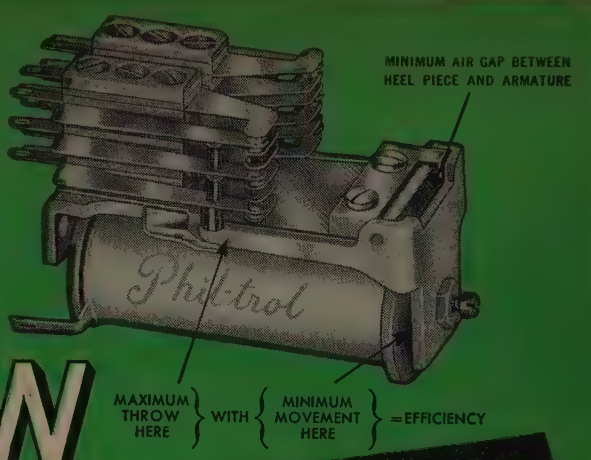
Either the 5MC WWV or the 15 MC WWV may be received. The receiver will accommodate any local frequency in the range from 50kC to 10MC equal to a subharmonic of 10MC, 2MC or 400 kC. A second channel receives the audio modulation and time signals of the WWV-Standard.

Four models available.

| | WWV Input 5.0 MC | 5.0 and 15.0 MC |
|---|---|---|
| Audio Modulation on Speaker Phone Jacks | Model ME-117A<br>$865.00 | Model ME-117C<br>$910.00 |
| Additional Filter for 440/600 CPS | Model ME-117B<br>$940.00 | Model ME-117D<br>$985.00 |

F.O.B. Matawan, N.J.

Phillip H. Harrison & Co.
Route 34, Matawan, N.J.
Matawan 1-3113, 1-4242
Write for Illustrated Descriptive Pamphlet



NEW

6QA Phil-trol RELAY

Adds Sales Appeal and Top Performance to Your Products

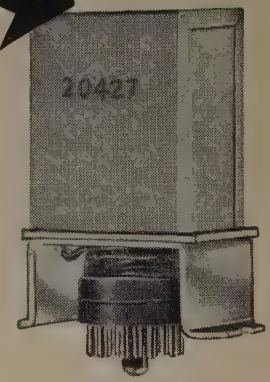
The new Phil-Trol 6QA Relay has found wide acceptance in a variety of products because of its extreme compactness, capacity and exceptional sensitivity.

The 6QA is only 2 9/16" long, yet it provides large cubic area for winding (maximum 20,000 ohm coil). Armature ratio and electro magnetic features assure high sensitivity.

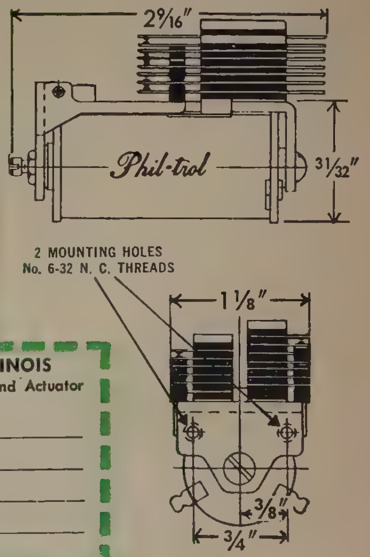
Phil-Trol 6QA performance equals that of larger telephone type relays. Its construction makes possible mounting and wiring from under the chassis, using less space and saving assembly time and costs.

For added convenience, the Phil-Trol 6QA Relay is available with a plug-in adaptation for use in panels and annunciator racks.

Phil-trol
IS THE REGISTERED TRADE MARK OF
PHILLIPS CONTROL CORP., JOLIET, ILLINOIS
OFFICES IN ALL PRINCIPAL CITIES



PLUG-IN—
DUST COVERED
TYPE 6QA—(Quick Acting)



PHILLIPS CONTROL CORP., DEPT. PI, JOLIET, ILLINOIS
Please send me a free copy of the new Phil-Trol Relay and Actuator Catalog.
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Company______________
Address______________
City______________Zone______State______

CO-AX
4 mmf/ft

★ ULTRA LOW capacitance & attenuation

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TO HANDLE DIRECT ORDERS OR
ENQUIRIES FROM OVERSEAS
SPOT DELIVERIES FOR U.S.
BILLED IN DOLLARS—
SETTLEMENT BY YOUR CHECK
CABLE OR AIRMAIL TODAY

| TYPE | μμF/ft | IMPED.Ω | O.D. |
|---|---|---|---|
| C 1 | 7.3 | 150 | .36" |
| C 11 | 6.3 | 173 | .36" |
| C 2 | 6.3 | 171 | .44" |
| C 22 | 5.5 | 184 | .44" |
| C 3 | 5.4 | 197 | .64" |
| C 33 | 4.8 | 220 | .64" |
| C 4 | 4.6 | 229 | 1.03" |
| C 44 | 4.1 | 252 | 1.03" |

TRANS RADIO

NEW 'MX and SM' SUBMINIATURE CONNECTORS
Constant 50Ω-63Ω-70Ω impedances

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## News-New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

*(Continued from page 101A)*

### New Literature

Eng-Data sheet #20201-1, entitled "Hi-Altitude Nomograms," released by **Rotron Manufacturing Co.**, Schoonmaker Lane, Woodstock, N. Y., offers the design engineer a practical short-cut to calculating volumes and weights of cooling air required in diverse airborne applications. The data sheet covers 8 pages of graphs and nomograms, and includes short text examples pertaining to typical practical cases. These examples are divided into two categories, for laminar and turbulent flow.

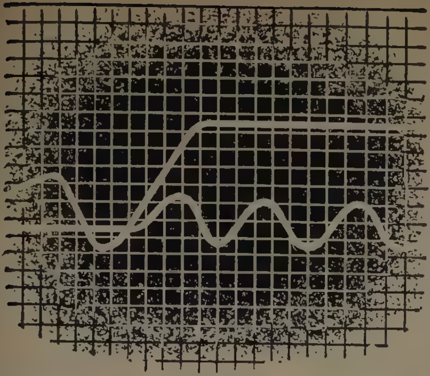
Some of the nomograms are the result of considerable mathematical work, and derivations of the formulas used are available. Copies may be obtained on letterhead request.

### Silicon Transistors

Expansion of its line of silicon transistors from three to five types is announced by **Texas Instruments Inc.**, 6000 Lemmon Ave., Dallas 9, Texas. One has an alpha (current amplification factor) of 0.975 or better and one an alpha cutoff frequency of 8 mc or better. TI states that current production capacity allows deliveries of silicon transistors in unlimited quantity.

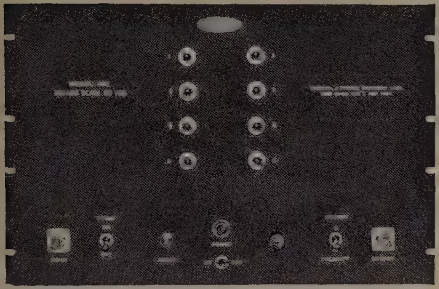
Grown-junction silicon transistors operate with little change at 150°C (302°F), while the equivalent limit for germanium transistors is 65°C (149°F). Average alpha cutoff frequency is 3 mc for three of the types, with alpha guaranteed to be from 0.90 to 0.95 with Type 903, 0.95 to 0.975 with Type 904, and 0.975 or better with Type 905. Type 904A has an alpha cutoff frequency of 8 mc or better and an alpha of 0.95 or better. The Type X-15 large signal unit gives a power gain of 14 db with collector dissipation of 1 watt in Class B operation. The firm states also that silicon transistors may even replace germanium units in applications where temperature is not a factor, because of their superiority in such other vital characteristics as frequency, rise and decay times, and power output. For more detailed information on silicon transistors, write for Bulletin DL-S 426.

*(Continued on page 104A)*



EPIC

# EPIC FAST PULSE AND COUNTING EQUIPMENT



*Proved Dependability In A Versatile Range Of Assemblies*

**0.001 MICROSECOND RISE TIME SQUARE PULSE GENERATORS** for the millimicrosecond to microsecond range.

**0-10 MC DECADE AND BINARY SCALERS FULLY AUTOMATIC 0-10 MC NUCLEAR SCALERS** with predetermined count, predetermined time operation, precision high voltage power supplies, preamplifiers and discriminators.

- **PLUG IN COUNTING STRIPS**
- **0.1 MICROSECOND COUNTER CHRONOGRAPHS**
- **PRECISION DC HIGH VOLTAGE SUPPLIES**
- **WIDE BAND AMPLIFIERS**

**ALSO CUSTOM DESIGNED EQUIPMENT TO MEET YOUR INDIVIDUAL REQUIREMENTS!**

*Write for detailed engineering bulletin No. 402*

EPIC

***ELECTRICAL AND PHYSICAL INSTRUMENT CORPORATION***
**Engineering Division**
**42-19 27th Street, Long Island City 1, N. Y.**

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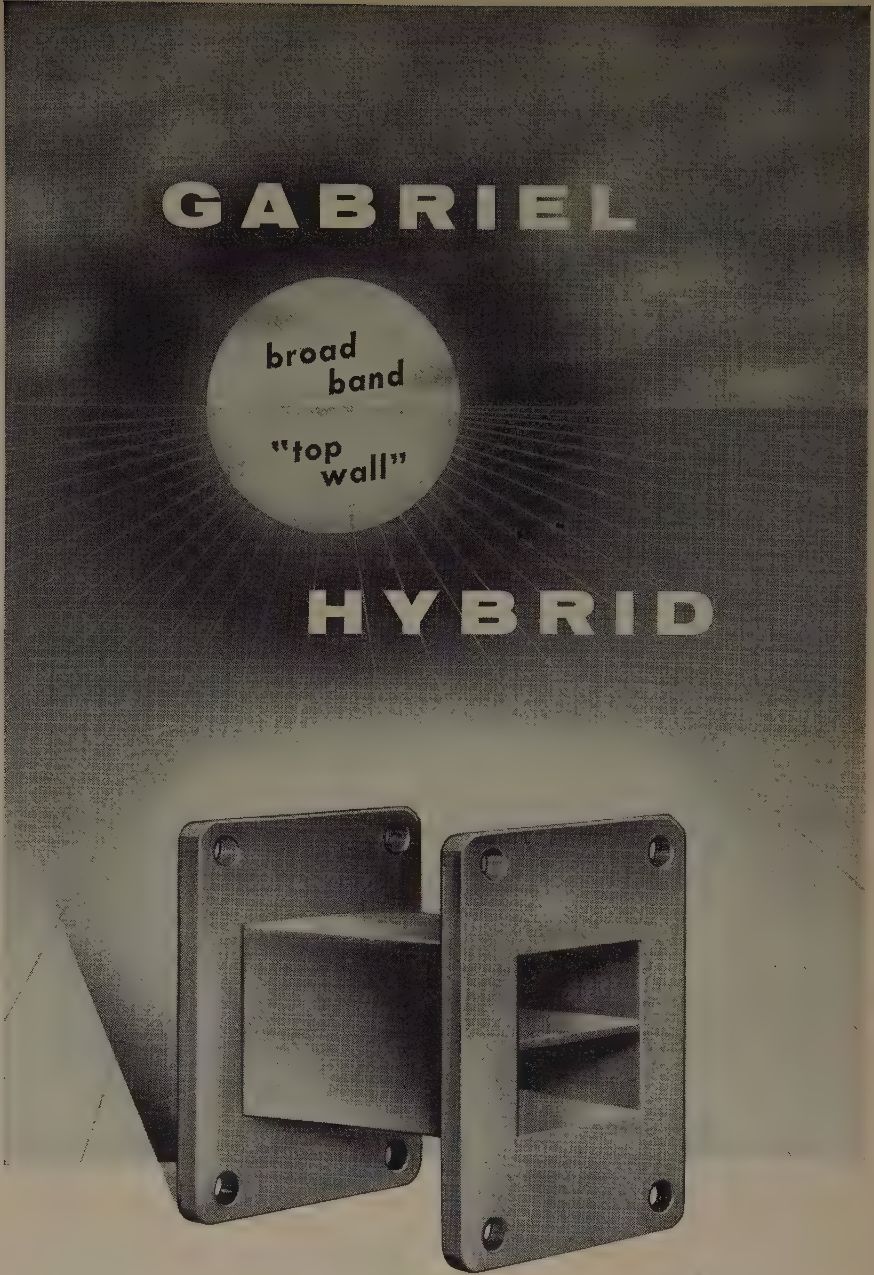

"Top wall" construction plus integral flanges make this waveguide component small, compact, and very easy to install. High-precision casting to close tolerances assures exceptional electrical performance and mechanical strength.

| | |
|---|---|
| *frequency* | 8200-9700 mc |
| *coupling* | (power division) 0.25 db |
| *isolation* | in excess of 35 db |
| *input VSWR* | less than 1.07 |
| *material* | beryllium copper or aluminum |

Available for immediate delivery . . . and at extremely low cost. For more information about this hybrid, or other waveguide components from our complete line, write, or phone NEedham 3-0005.

**The Gabriel Laboratories**
DIVISION OF THE GABRIEL COMPANY 135 Crescent Street, Needham Heights, Mass.

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POWER SUPPLIES

MODEL M60VMC

0 to 32 VOLTS @ 25 AMPS. (Cont.)

REGULATION: ±1%*(a) At 28 V. D.C.—Increases to 2% max. over the range 24-32 V.; does not exceed 2V. regulation over the range 4-24 V. D.C. (b) From 1/10 Full Load to Full Load. (c) At a fixed A.C. input of 115 V.
RIPPLE: 1% rms @ 32 V. and Full Load—2% rms. max. @ any voltage above 4 V.
A.C. INPUT: 115 V. Single Phase, 60 c.p.s.
WEIGHT: 130 lbs.
FINISH: Baked Grey Wrinkle.
DIMENSIONS: 22"x15"x14½"
*This unit is an economical solution to your power supply needs if stabilization for A.C. Voltage changes are not required. If this is required, write for spec. on Model MR1040-30.
Price: $439 w/o cabinet, $474 w/cabinet
All prices F.O.B., El Segundo, Terms: 1%-10 days, net 30 Phone collect for quantity discounts.

Write for Bulletin MA 154 . . . also write (on company letterhead) for free subscription to technical periodical PERKIN POWER SUPPLY BULLETIN.

PERKIN D C power supplies

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TORQUE WRENCHES
Read by Sight, Sound or Feel.

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in inch grams...inch ounces,...inch pounds ...foot pounds (All sizes from 0-6000 ft. lbs.)

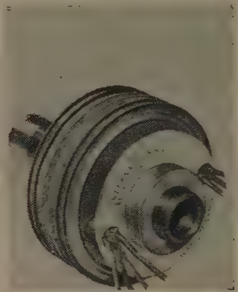
Every manufacturer, design and production man should have this valuable data. Sent upon request.

P.A. Sturtevant Co
ADDISON QUALITY ILLINOIS

(Continued from page 102A)

## Rotating Selenium Rectifier

A rotating selenium rectifier developed by **International Rectifier Corp.,** 1521 E. Grand Ave., El Segundo, Calif., makes it possible to eliminate commutators and slip rings in dc generators. The basic principle of applying a rotating rectifier is to mount the unit on the same shaft with the alternator field and ac exciter. Exciter field is fed from an external dc supply, which may be another rectifier and a variable transformer. Output from the exciter, usually 3-phase, is connected directly to the alternator field windings. Using an ac exciter eliminates the commutator, and since the rotating rectifier is on the same shaft with the alternator field the usual slip rings are not required. This eliminates wear and sparking and the resulting rf interference and brush maintenance.



The rotating rectifier pictured uses six individual 5-inch-diameter selenium plates. It is used to supply power to the field of a 30 kw diesel generator set, and will deliver 750 watts at 30 volts. Circuit design information for rotating rectifiers may be obtained from the manufacturer.

## Convergence Dot Generator

**Wickes Engineering & Construction Co.,** 12 St. & Ferry Ave., Camden 4, N. J., has a new Model CDG-1 Convergence Dot Generator; a precision instrument designed to check the adjustment of the beam-positioning magnets, dynamic convergence, and dc convergence of color video monitors and receivers. The CDG-1 will also check the linearity, focus, and centering of color and monochrome video monitors and receivers.

A convenient selector switch allows a choice of four separate patterns; a stationary pattern of dots, a grating pattern of vertical and horizontal bars, a pattern of horizontal bars, and a pattern of vertical bars. The size and number of the dots and the size and spacing of the bars are adjustable.

(Continued on page 109A)

*(Continued from page 104A)*

The CDG-1 is designed so that both the vertical and horizontal counters are locked to the horizontal drive signal. The horizontal drive signal can be of negative or positive polarity. The composite blanking input signal can also be either positive or negative. When a source of composite sync is available, the CDG-1 will produce a composite video signal which can be fed directly to a video monitor. The video signal can also be fed to a receiver, through a low-powered video modulator.

The CDG-1 incorporates a built-in filament supply, and is designed for standard rack mounting. Brackets are supplied for bath-tub and internal-rail mounting. All controls and adjustments are accessible on the front panel. Test points are incorporated in the major circuits.

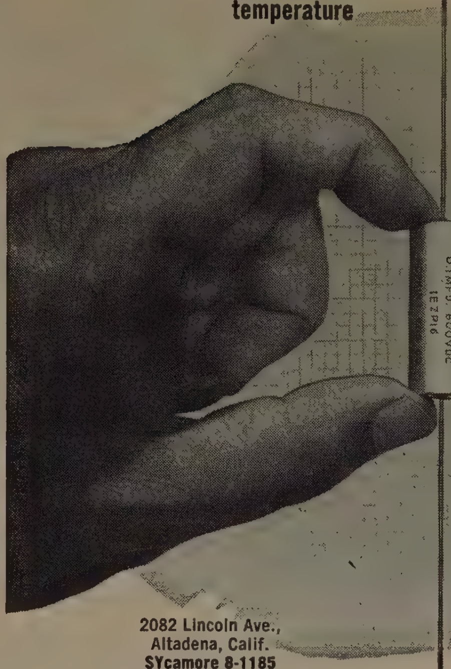
## Computation Center for Delaware Valley

A major industrial computation center has been opened by **Burroughs Corp.** at the headquarters of its **Electronic Instruments Div.,** 1209 Vine St., Philadelphia, Pa.

The Burroughs high-speed, automatic computer UDEC II, the third of its type to be built, cost an estimated $250,000. Its services and those of the ten-man Burroughs computation staff will be rented at a fee of $75 an hour to solve problems in management planning, product design, systems analysis and data reduction. UDEC II, heart of the Burroughs computation center, is a C-shaped giant seven feet high and sixty feet long. It was constructed within sight of the public. Starting in mid-June, when Burroughs razed its former Laboratory Computer and began putting the parts back together into the faster, more versatile UDEC II, people have had an opportunity to view the step-by-step assembly and testing of the huge machine.

UDEC II does its computing with the help of more than 3000 vacuum tubes, more than 7000 germanium diodes and approximately five miles of interconnecting cable. The machine also contains a spinning magnetic drum memory capable of storing 5300 ten-digit numbers.

*(Continued on page 110A)*



for all applications
requiring exceptionally
high insulation
resistance and unusual
stability at high
temperature

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"HY-THERM"
New sub-miniature
high temperature
CAPACITOR

Hermetically sealed and metal encased, new HY-THERM capacitors have been designed to meet or exceed military requirements (Mil-C-25A). **Example:** At 125°C the minimum insulation resistance is 20 megohm-microfarads and maximum insulation resistance is 500 megohms. Available in all standard values and tolerances. Variety of mounting and circuit combinations. Special units designed to meet individual requirements.

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Offices in
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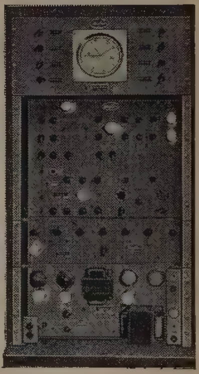
**Have a special problem? Write, wire or phone for details, TODAY! Catalog available.**



Wickes

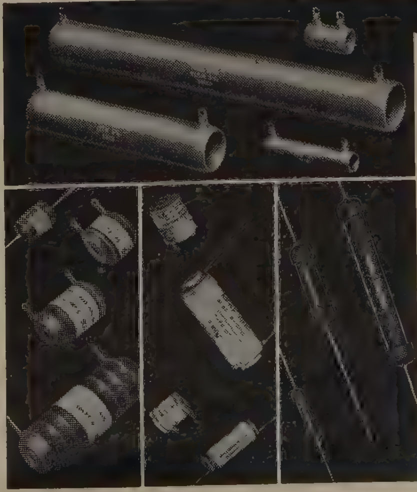
VECTOR DISPLAY EQUIPMENT
MODEL VDE-3A

►COMPLETELY RACK-MOUNTED ►RACK INCLUDED

Color television vector display monitoring and test instrument. Includes high-definition display oscilloscope of special design. Edge-lighted calibrated overlay, with adjustable illumination. Camera mounting facilities for photographic records of vector display, plus continuous operating check. Equipment includes all self-calibrating features for accurate and dependable signal certification. Protective covers for safe portability. Rack Oscilloscope, Decoder-Keyer, and Burst-Controlled Oscillator available as separate items. Details forwarded on request.

*Write for data on our complete line of color television instruments for signal generating, distribution, test, and measurement.*

Wickes ENGINEERING AND CONSTRUCTION COMPANY
12TH STREET AND FERRY AVENUE
ESTABLISHED 1920
CAMDEN 4, NEW JERSEY



PRECISION RESISTOR HEADQUARTERS

"Akra-Ohm" ceramic wirewounds (Bulletin R-35); "P-Type" epoxy resin encapsulated wirewounds (Bulletin L-30); "Borohm" boro-carbon film types (Bulletin L-33); "Castohm" lightweight cast ceramic power resistors (Bulletin L-29).

All commercial, industrial, JAN, and MIL types. Pioneers in precision resistors—SHALLCROSS MFG. CO., 524 Pusey Ave., Collingdale, Pa.

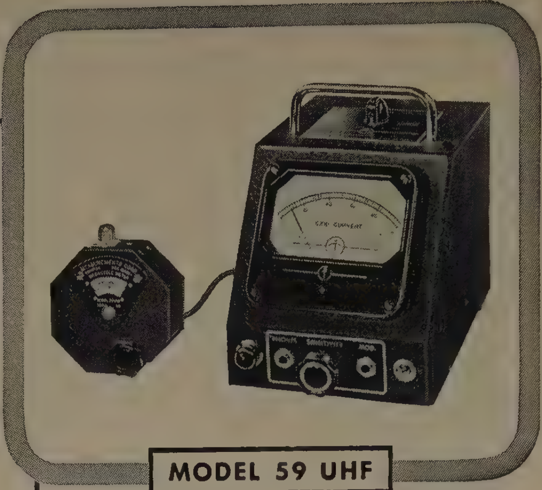
SHALLCROSS

**NEW UHF MEGACYCLE METER**

**With the Widest Frequency Coverage in a Single Band**

FEATURES

- Excellent coupling sensitivity.
- Fixed coupling point.
- Small grid current variation over band.
- Calibration point every 10 Mc.
- Uses split-stator tuning condenser with no sliding metal contacts.
- Standard camera socket for tripod fixtures.
- Octagonal case for convenient positioning.
- Useful in television transmitting and receiving equipment.



MODEL 59 UHF

*SPECIFICATIONS*

FREQUENCY RANGE: 430-940 Mc in a single band
FREQUENCY ACCURACY: ±2% (Individually calibrated)
OUTPUT: CW or 120-cycle modulation
POWER SUPPLY: 117 volts, 60 cycles, 30 watts
DIMENSIONS: Oscillator Unit 4⅝" x 2½"
Power Unit 5⅛" wide x 6⅛" high x 7½" deep

Laboratory Standards
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SYNTRON COMPANY
242 Lexington Avenue
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These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

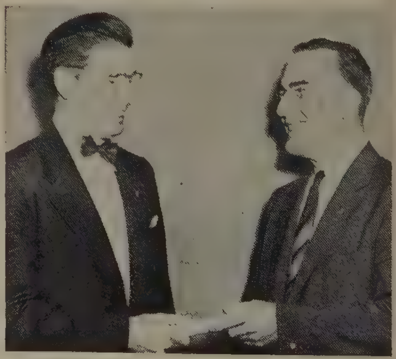
*(Continued from page 109A)*

## Polystyrene Capacitors

The stability of capacitors which use polystyrene as the dielectric has been increased by a new production technique developed by **Condenser Products Co., Div. of New Haven Clock and Watch Co.,** 140 Hamilton St., New Haven, Conn.

This technique involves a series of heating and aging cycles which have a marked effect on the stability of the film. These polystyrene capacitors have a room-temperature capacity drift of less than 0.1 per cent over a temperature range of from −80°C to +75°C. Under the new heat and aging methods, the temperature coefficient of capacitance is less than 1.5 per cent overall capacity change in a temperature range of from −60° to +85°C. The firm claims that these units can be used as standard capacitors in decade condenser boxes; as charge storage capacitors where self time constants of 5,000 hours or more is required; and in resistance capacitance networks where stability and temperature coefficient of capacitance is critical.

## Colvin Given Audio Award



At the annual meeting of the **Audio Engineering Society** held in New York City recently, Mr. John D. Colvin, Director of Engineering for the Gates Radio Company Quincy, Illinois, was presented with the Society's annual award. This citation was given for his efforts and accomplishments in the formation and progress of the Society.

*(Continued on page 113A)*

(Continued from page 110A)

## Conductive Silver Coatings

**Micro-Circuits Co.,** New Buffalo, Mich., announces availability of their new S31 Basic Laboratory Kit, containing six electrically-conductive silver coatings, six resistance coatings, six accessory chemicals, manuals, data folders, etc. Quantities of each material range from one ounce to one pint.

PRINTED CIRCUITS
S31

The new kit contains those materials which, during the past five years, have been the most widely used and effective aids in solving research and design problems in a wide variety of industries.

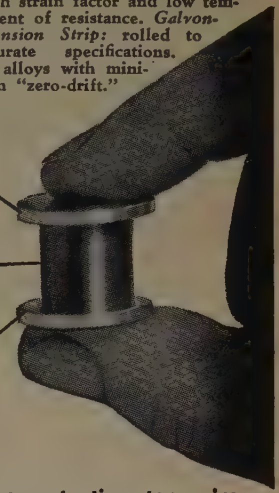
Conductive coatings usually appear in manufactured products only when these products have electronic or electrical components; but the usefulness of these relatively new materials in solving problems at the research and development level has brought them into wide use in such varied fields as biochemistry, petroleum exploration, air conditioning, ceramics, the automotive, industry, aircraft, acoustics, and insulation.

## DC Power Rectifiers

A new line of power rectifiers has been announced by **McColpin-Christie Corp.,** 3410 W. 67 St., Los Angeles 43, Calif. "C&C" Stavolt units are closely regulated by a unique magnetic amplifier control of stable and permanent qualities. No tubes, lamps, carbon piles, or varistors are employed. Ten standard 28-volt production models with capacities up to 1000 amperes are available in either mobile or stationary types.

This power supply meets the requirements, both as to range and characteristics, of MIL-E-7894 specification for aircraft equipment and components.

(Continued on page 114A)



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bare • insulated plated ⊙

for highly engineered applications

all metals all alloys

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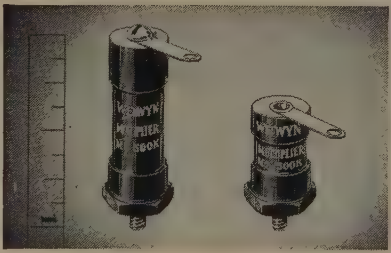
WHite Plains 9-4757

Write for Pamphlet P



METER MULTIPLIER
DEPOSITED CARBON RESISTORS

Designed specifically for panel instrument circuits, Welwyn Meter Multipliers offer definite advantages in both size and economy over previously employed, bulkier and costlier, wire wound units.

Welwyn Meter Multipliers find their greatest application where circuit performance permits stability limits in the order of .25% to .5%. Physically, these resistors are ideally suited for mounting in restricted space, yet they provide ample, convenient tie-in points for connecting other circuit components.

Welwyn Meter Multiplier values range from 20 ohms to 1 megohm.

*Manufactured in England and Canada*

For complete data and specifications write to Dept. LM-4

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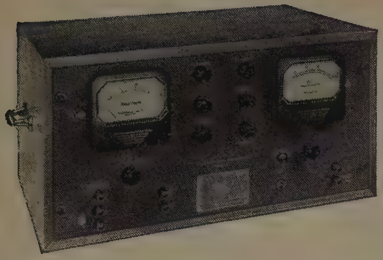
DEPOSITED CARBON RESISTORS

ROCKBAR CORPORATION 215 East 37th Street, New York 16, N. Y.

AUTOMATIC! Transistor Noise Figure Measurement



Now available, a new instrument for transistor Noise Figure measurement.* Automatically indicates Noise Figure of all types of transistors and transistor amplifiers on a continuous reading basis. Just plug in the transistor or amplifier and read Noise Figure directly on the meter!

*Model NFT Transistor NF Meter*

- √ For Laboratory and Factory Applications
- √ Quality Control, Production Testing
- √ Low Noise Figure Selection and Evaluation
- √ Optimization of Circuit and Operating Parameters
- √ Rating and Specification Checks
- √ Trouble Shooting of Transistor Devices
- √ Reliability Evaluation

*Specifications*

Noise Figure Range ..........5 to 65 db
Measurement Freq. ........1000 cps center F.†
Type of Reading ............Direct Reading
Input Circuit ...........500 ohm emitter R.
Emitter Supply .............Ie, 0-1.0/10 MA
Collector Supply ..........Ec, 0-10/100 volts
Indicating Meters ...............4½" meters
Hardwood Case, 8¾ x 19" Panel, 14" Depth

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*Patents Applied For
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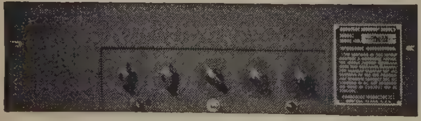

RACK MOUNTING MODELS

105-125 V. 60C INPUT
OUTPUT CURRENT MAY BE SET AT ANY VALUE FROM 0.2 TO 50 M.A. D.C. AS LOAD VOLTAGE VARIES BETWEEN 0-150 V. MODEL 1A-R IS CONSTANT WITHIN 1%. MODEL 1B-R WITHIN 0.1%.

IMMEDIATE DELIVERY
MODEL 1A-R $112—MODEL 1B-R $245
0.2-100 M.A. RANGE $13 MORE
*Other models to specifications*

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OUTPUT CURRENT IS HELD CONSTANT AS LOAD VARIES

OTHER MODELS AVAILABLE
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## News-New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

*(Continued from page 113A)*

The specifications are as follows: The unit is continuously variable between 25–29 volts dc; dc regulation ±1.0 per cent with ±10 per cent change in the ac input and any load variation from zero to full load; dc ripple 2.0 per cent RMS; recovery time 0.2 seconds. This unit is available for parallel operation. Other ranges and closer tolerances can be furnished.

For complete information write to McColpin-Christie Corp. for Bulletin AC-54.

### Resistance Meter

A new regulation meter, Model D-1, which provides direct measurement of power supply internal resistances without a complex laboratory setup is now being manufactured by **Alto Scientific Co.,** 2404 Cowper St., Palo Alto, Calif.

The new instrument measures resistances directly from 0.02 to 1000 ohms in voltage sources with outputs ranging from 0 to 500 volts. The instrument may also be used as an ac voltmeter for measurements from 5 cps to 10 kc. It further serves as a general linear ohmmeter, and measures ripple and noise.

Output terminals are provided so that transient response may be viewed on an oscilloscope; or so that the voltmeter output can be viewed in general testing. Four linear resistance ranges are provided; 0–1, 0–10, 0–100 and 0–1000 ohms full scale. There are also four voltage ranges: 0–10 mv, 0–100 mv, 0–1 v and 0–10 v RMS full scale.

### Null Meter Brochure

**Industrial Test Equipment Co.,** 55 E. 11 St., New York 3, N. Y., has released a brochure describing their Phazor Null Meter Model 100A and an article entitled "Null Detection of Complex Waveforms." The article demonstrates the usefulness of this instrument for nulling bridges, potentiometers, synchros, resolvers, and allied devices.

*(Continued on page 116A)*

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SERIES M200

**Miniature i. f. Amplifiers**

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Here's a brand new way to design i. f. strips! Simply reach for your purchase order pad, specify the characteristics you desire, and mail to Instruments for Industries, Inc. Standard models are available from stock, special designs get prompt attention from our engineering and production staff.

I. F. I.'s fast, convenient service on i. f. strips and other types of broad-band amplifiers has saved valuable design and production time for many leading companies. Write for complete details.

Specifications of Standard Units

| | M260 | M230 | M231 | M235 |
|---|---|---|---|---|
| Band center | 60 mc | 30 mc | 23.5 mc | 30 mc |
| Band width | 10 mc | 2 mc | 2 mc | 10 mc |
| Voltage gain | 90 db | 110 db | 110 db | 90 db |
| Output power | 0.02 W | 0.1 W | 0.1 W | 0.04 W |
| Input impedance | 50 ohms | 50 ohms | 50 ohms | 50 ohms |
| Input V. S. W. R. less than | 1.3:1 | 1.3:1 | 1.3:1 | 1.3:1 |

Note: M230 model available with 1.5 db noise figure

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**DC-AC CONVERTER**

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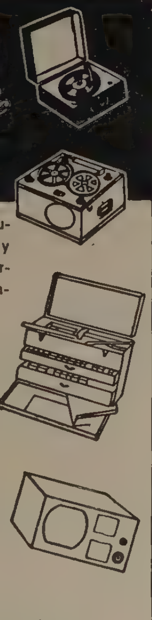

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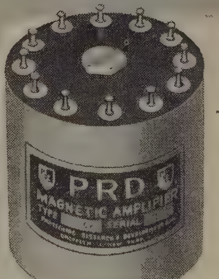

- Response time of one cycle
- Temp. range −55°C to +85°C
- Power supply 115V, 400 cps, single phase
- Hermetically sealed reactor unit only 2½" high and 2¼" diam., weighs less than 12 oz.

The R40G10W1 can be supplied either as illustrated or with a built-in magnetic, transistor, or vacuum tube preamplifier. The moisture and fungus proofed rectifier is supplied for external mounting. This economical and rugged unit is ideal for integration with servo systems requiring Mark 7 or 8 motors. Write for details.

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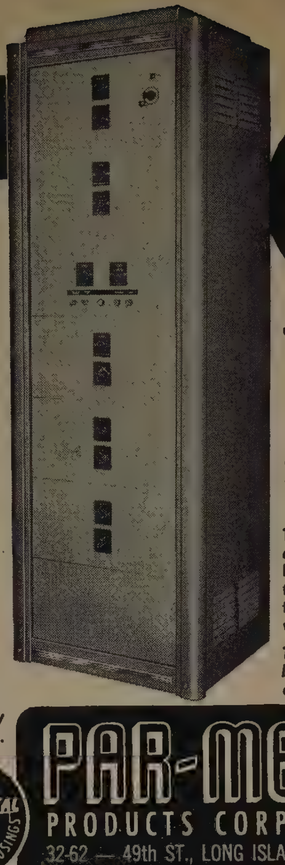

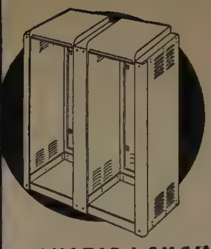

**"MULTIRACKS"**
These Racks may be assembled in multiple units as shown above.
SHELVES available.
Also ROLLER TRUCKS available for single racks or "Multiracks".

**NO INCREASE IN COST!**
The *ER-225* is priced to compete with racks not having the equivalent features. Beyond doubt—*it's the industry's greatest value.*

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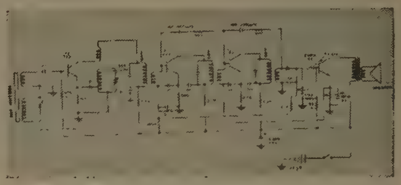
*(Continued from page 114A)*

## Transistor Receiver for Consumer Use

**Regency, Div., I.D.E.A., Inc.,** 7900 Pendleton Pike, Indianapolis 26, Ind., has engineered a pocket receiver which measures 3 by 5 by 1¼ inches and weighs less than 12 ounces. Many of the sub-miniaturization techniques employed in military and aircraft weight and size reduction programs were used to produce this new Model TR-1.



The core of the receiver is a 4 *n-p-n* type mass produced, low cost, high gain, high-frequency germanium transistor supplied by Texas Instruments. Power gains of 34 and 40 are achieved in the IF and af stages respectively. Because of the low drain only one battery of reduced size is employed.

Each component supplier developed special items to aid in size and weight reduction. Jensen of Chicago designed a speaker that was more efficient and distortion-free than others of its class; Radio Condenser Co. of Camden, N. J., produced a new small tuning condenser; Vokar Corp. of Dexter, Mich., designed a diminutive intermediate-frequency transformer unique in size and construction; Chicago Telephone Supply Corp. of Elkhart, Ind., created a miniature low-cost volume control; and Centralab, a division of Globe Union, Inc., Milwaukee, provided a very small ceramic capacitor. Printed circuits and dip soldering techniques were used on the chassis.

## Vacuum Tube Characteristic Curves

Vacuum-tube circuit design is simplified by use of the large-size vacuum-tube characteristic curves offered by **Technical Publishing House,** P. O. Box 61, Waltham 54, Mass. The curves, on 8½ by 11-inch pads, show average plate characteristics, positive-grid characteristics $u$, $g_m$, and $r_p$, plus screen characteristics for pentodes. For ease of reading, all graph scales have been standardized to 1, 2, or 5 units per scale division. The reverse side of the sheet gives tabulated electrical and mechanical data and ratings for the tube, and for all electrically-equivalent types, showing similarities, differences, and special features.

Pads are available from stock for tube types 12AU7, 12AX7, 12AT7, 6SL7, 6SN7, 6L6 pentrode, 6L6 triode, 6AQ5 pentode, 6AQ5 triode, 5965, 5687, 5751, 5718, and their single-unit, industrial, aircraft, military, rugged, and computer equivalents. Each pad has 20 identical sheets.

*(Continued on page 132A)*

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*(Physicist or Electronics Engineer)*

Once in a lifetime opportunity for physicist or electronics engineer with ability to design, construct and install setups used to obtain data on engine ignition and performance. Setups will be diversified so that projects might require mechanical and electronics instrumentation as required to best obtain information.

Also included will be design of auxiliary control circuits and writing of operation manual to be used by experimental department personnel.

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Position requires applicant capable of designing circuits incorporating transistors, magnetic amplifiers and semi-conductors.

Interested applicants possessing necessary qualifications are invited to write at once, outlining all pertinent data regarding responsibilities of present position, past experience, training and salary requirements.

Address letters to:
Personnel Director
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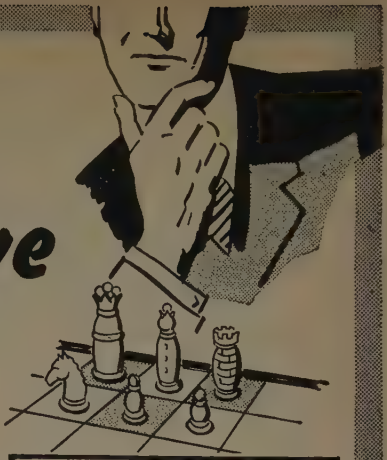
Toledo 1, Ohio



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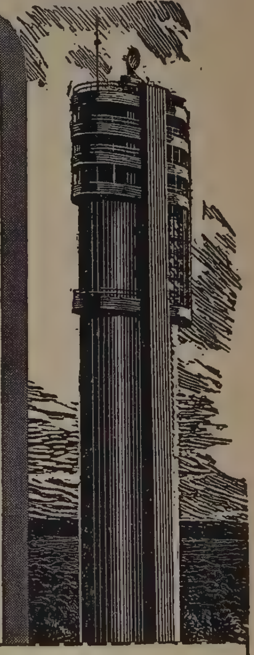

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- Transistor development

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WRITE: J. A. Chambers, Manager
Motorola Research Laboratory
3102 North 56th Street
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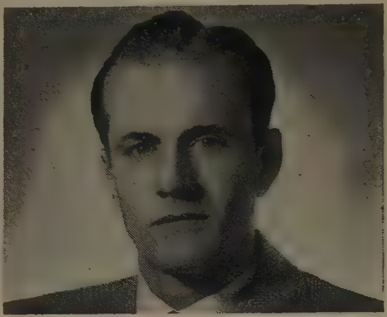
## News-New Products

*(Continued from page 116A)*

### Corben Joins Ramo-Wooldridge

Dr. Herbert C. Corben, internationally known research physicist and scholar, has joined the staff of the **Ramo-Wooldridge Corp.**, Los Angeles, Calif., electronic research and development firm, as physicist in their Guided Missile Division.



Dr. Corben was graduated from the University of Melbourne with a M.A., M.Sc. in 1936 and received his Ph.D. degree in Theoretical Physics from the University of Cambridge in 1939. He served on the staff of the Carnegie Institute of Technology for six years as professor of physics, and for two years was visiting professor in Italy on the Fulbright Commission.

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Men with interests in the above and related fields should submit resumes to Mr. H. F. Ware. Expenses will be paid for qualified applicants who come for interviews. We regret we can consider only U. S. citizens.

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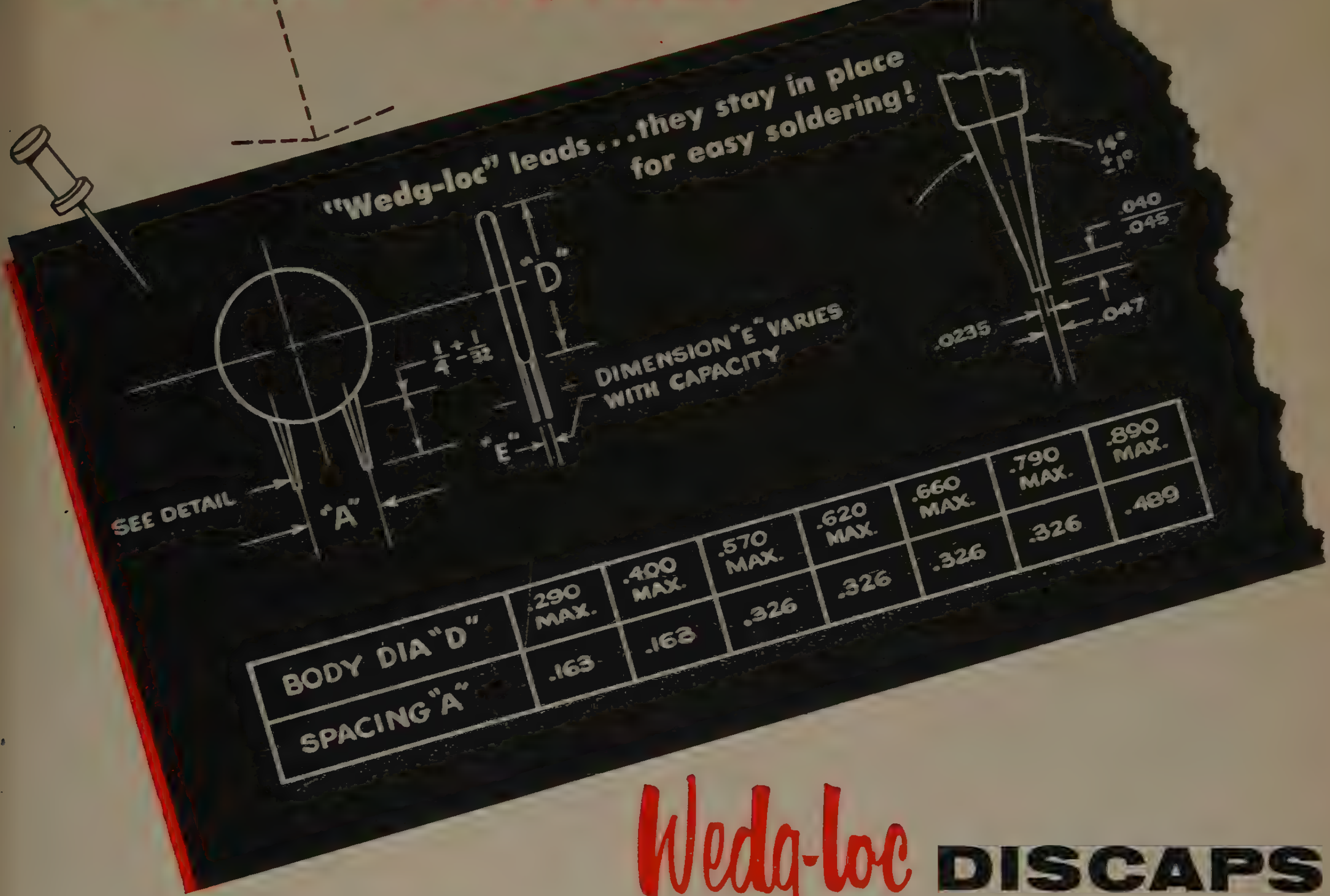
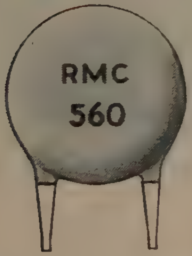
# Another RMC First

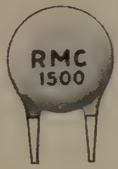

"Wedg-loc" leads . . . they stay in place for easy soldering!
SEE DETAIL
"A"
"D"
"E"
1/4 + 1/32
DIMENSION "E" VARIES WITH CAPACITY
14° ±1°
.040
.045
.047
.0235

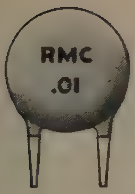
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| BODY DIA "D" | .290 MAX. | .400 MAX. | .570 MAX. | .620 MAX. | .660 MAX. | .790 MAX. | .890 MAX. |
| SPACING "A" | .163 | .163 | .326 | .326 | .326 | .326 | .489 |

# Wedg-loc DISCAPS

## for printed wire circuits







The exclusive wedge design of the leads on these new DISCAPS lock them securely in place on printed circuit assemblies prior to the soldering operation. The "Wedg-loc" leads eliminate the possibility of the capacitors becoming loose or falling out. Application of "Wedg-loc" lead DISCAPS to your printed circuits will cut production time, reduce costs, and insure the uniformity of your soldered connection.

"Wedg-loc" DISCAPS are available in capacities between 2 MMF and 10,000 MMF in temperature compensating, by-pass, and stable capacity types with lead spacing as shown above. Electrical specifications and tolerances are the same as standard wire lead DISCAPS. Your inquiry is invited.

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# He's using the telephone that lends an extra hand

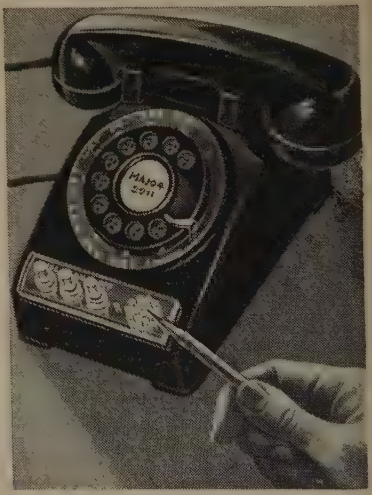
**"Sure . . . I'm looking up the figures right now!"** From busy executives to clerks, people in business can work more easily and efficiently with Bell's new Distant Talking Telephone. Small white rectangle is the loudspeaker.

For people who want to keep *both* hands free when they telephone, Bell Telephone Laboratories engineers have devised a new telephone with a sensitive microphone in its base.

To use it, simply press a button. The microphone picks up your voice and sends it on its way. Your party's voice comes to you through a small loudspeaker. Both hands are left free.

The volume can be adjusted to suit yourself. If privacy is needed, you simply lift the handset; this shuts off the microphone and loudspeaker and you talk just as you would on a regular telephone.

This new development of Bell Laboratories increases the number of ways your local Bell telephone company can serve in businesses and homes.

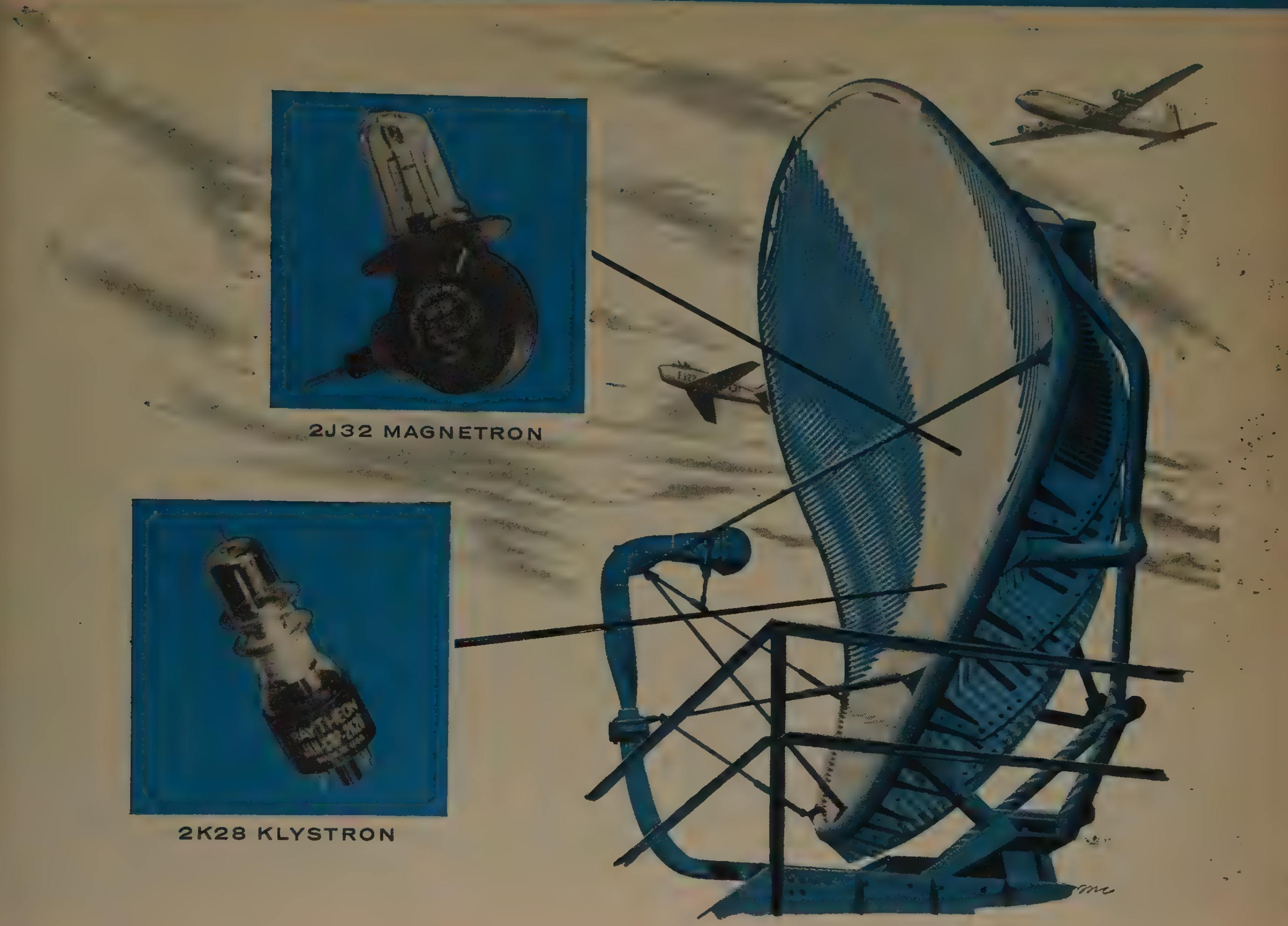


Pencil points to microphone in base of new telephone. Left-hand button controls volume, center one turns set "on" and lights up while in use. The third is an "off" button.

## Bell Telephone Laboratories

*Improving telephone service for America provides careers for creative men in scientific and technical fields.*

Raytheon — World's Largest Manufacturer of Magnetrons and Klystrons



# HELPING ESTABLISH RELIABILITY RECORDS

## Raytheon Magnetrons and Klystrons in proved Gilfillan ASR-1 Radar

Civil Aeronautics Administration reports record-breaking reliability of Gilfillan airport surveillance radar. Boston International Airport had 8,760 hours continuous performance with only 7⅓ hours involuntary outage—less than 1/10 of 1%—from their Gilfillan installation.

**Condensed Typical Operating Data**

| | Power Output | Frequency Range, mc | Reflector Voltage | Resonator Voltage | Maximum Temp. Coef. | Tuning | Cavity |
|---|---|---|---|---|---|---|---|
| 2K28 | 140 mw | 1200-3750 | —140 v. to —300 v. | 300 v. | ±.15 | Mech. Inductive | Ext. |
| | Power Output | Frequency Range, mc | Anode kv | Anode Amps. | Pulse Width | P.R.R. | |
| 2J32 | 285 kw min. | 2780-2820 Fixed freq. | 20 | 30 | 1 μsec | 1,000 | |

Check these performance records of Raytheon tubes in the Gilfillan ASR-1. Average life, 2J32 Magnetron: 4,000 hours. Average life, 2K28 Klystron: 2,500 hours.

Your microwave and radar equipment offers extra reliability when you specify Raytheon Magnetrons and Klystrons. Use these rugged, reliable tubes in your present and proposed systems. Contact Power Tube Sales to take advantage of Raytheon's Application Engineer Service, without obligation. Write for free Tube Data Booklets.

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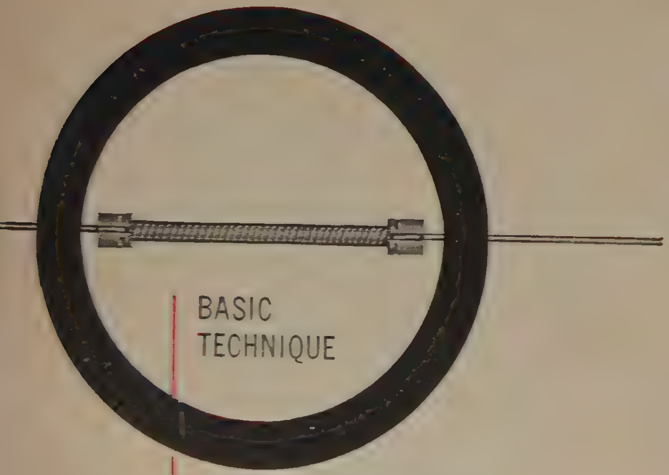
# ONLY IRC WINDING SKILL OFFERS



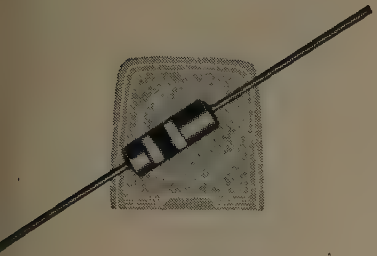
## BASIC TECHNIQUE

Wire element is uniformly and tightly wound on an insulated core. Axial leads or other terminations are secured to element by automatic machinery. Insulated housing may be used or omitted.

If you seek savings in component costs, IRC's winding skill may serve your need. IRC's mastery of winding wire elements dates back more than 25 years. Today, it provides a wide variety of unique units that offer realistic possibilities for savings. Cost-conscious IRC engineers will glady analyze your requirements.

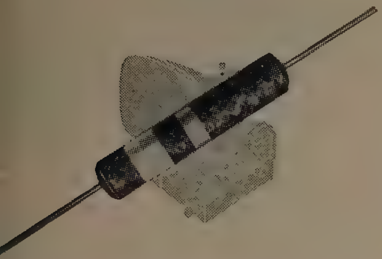
## *14c savings per car*

Type AW Wire Wound resistors save automobile manufacturers an average of 14c per car. For quantity requirements, these low-cost windings can be made specially to suit individual designs. This adaptability has proved profitable to numerous appliance manufacturers.



## *low cost—low wattage*

Type BW insulated wire wounds offer excellent stability in low ranges—at low prices. Leading instrument manufacturers attest to their superiority. ½, 1 and 2 watt sizes are equivalent to Jan types RU-3, RU-4 and RU-6



## *50% savings*

IRC Insulated Chokes offer savings up to 50% over ordinary types. Available in two sizes, they are fully protected against humidity, abrasion, assembly damage and danger of shorting to chassis. A favorite source of savings for TV and radio set manufacturers.

## THESE SAVINGS

## *inexpensive solution*

4-watt Insulated Power Wire Wounds with axial leads can save several cents over conventional power resistors. Inorganic core and high-temperature plastic housing allow safe operation up to 165° C. Widely used in toys, juke boxes and amusement devices.

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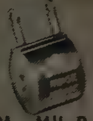


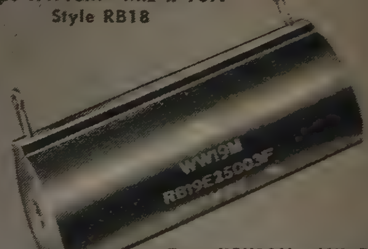
Type WW15M—MIL-R-93A Style RB15

Type WW16M—MIL-R-93A
Style RB16

Type WW17M—MIL-R-93A
Style RB17

WW18M
RB19E7500ZF

Type WW18M—MIL-R-93A
Style RB18



Type WW19M—MIL-R-93A
Style RB19

- **Epoxy Resin Compound Used For Both Winding Form and Seal.**
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On Daven Series 690 Attenuation Networks, the exclusive "plug-in" feature permits input or output impedance to be changed to any value by substituting "plug-in" pads of the particular impedance desired.

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To insure low contact resistance and uniform contact pressure Daven patented "knee-action" switch rotors are used. Silver alloy rotors, slip-rings and contacts insure finest electrical performance. Daven's exclusive "plug-in" impedance Matching Networks are available in a wide range of impedance and loss.

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FOR USE ON
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Each element . . . the vibrator, transformer and buffer capacitor . . . must be carefully selected for balanced electrical characteristics if your power supply is to give top performance in service.

You can avoid vibrator power supply trouble by calling on the specialized knowledge and experience of Mallory engineers. Let them translate the power requirements of your equipment into a smooth operating, trouble-free design. You will save time and money and get the kind of performance you want.

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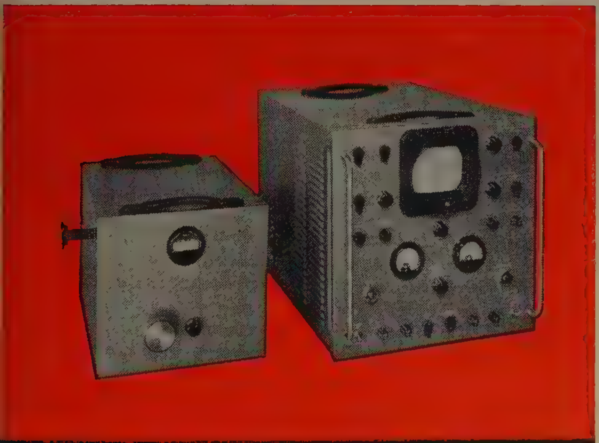
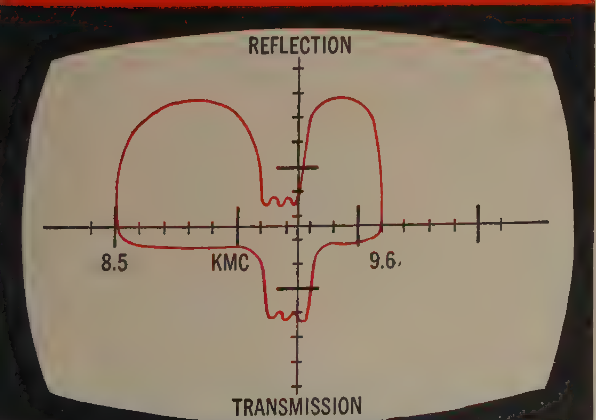
...saves engineering manhours

## wide band--8500 to 9600 mc; output constant within one db; for dynamic testing of microwave components and systems



Now, for the first time, an instantaneous graphic display of the entire frequency range 8500 to 9600 MCS. This new Polarad X-Band Sweep Oscillator makes possible rapid, dynamic testing of microwave components such as TR tubes, antennas, crystal mounts, even complete microwave systems over a 1100 MC sweep at X-band. Eliminates laborious point-by-point testing methods. A unique display unit shows both reflection and transmission characteristics simultaneously, since two deflection amplifiers are utilized.

The X-Band Sweep Oscillator is an important instrument for laboratory and production line application. It gives one quick answer where formerly hours of checking were necessary. For further information, write to your nearest Polarad representative or the factory.



**A Typical Scope Display** (at left)
Shows transmission and reflection characteristics of a double tuned cavity under test. This is an example of how the dynamic display reduces time required to test X-band components and systems. As a design tool in the laboratory, the effects of electronic or mechanical changes may be evaluated instantaneously.
As a production tool, "go" and "no go" limits may be checked visually.

SPECIFICATIONS

| | |
|---|---|
| Frequency Range: | 8.5 to 9.6 KMC |
| Output: | + 12 dbm minimum into matched load |
| Output Variation: | ± 1 db maximum |
| Sweeper Rate: | 12 cycles per second |
| Operating Voltage: | 115 V ± 10% |
| Input Power: | 400 watts |
| Type of Output Connector: | UG-52A/U |
| Size of Control and Display Unit: | 15⁹⁄₁₆" wide x 20⅞" deep x 16⅜" high |
| Size of Sweeper Oscillator: | 12" wide x 16¼" deep x 12" high |
| Approx. Wt. of Control and Display Unit: | 135 lbs. |
| Approx. Wt. of Sweeper Oscillator | 55 lbs. |

**Polarad** ELECTRONICS CORPORATION 100 METROPOLITAN AVENUE, BROOKLYN 11, NEW YORK

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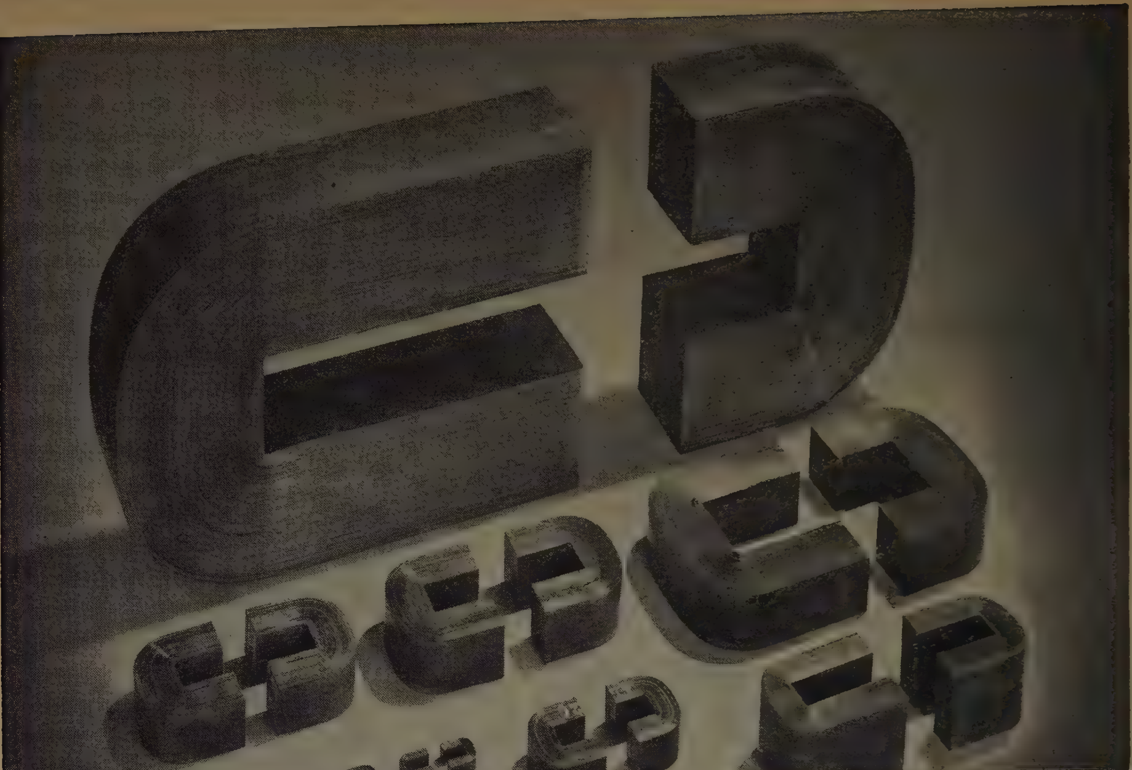
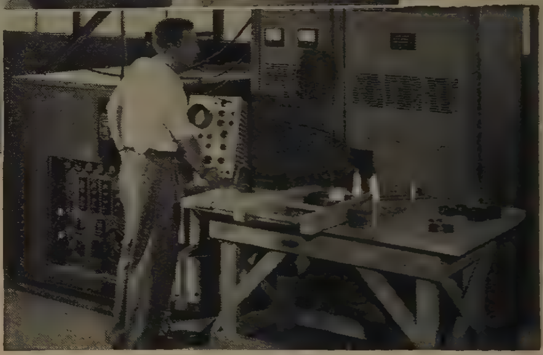
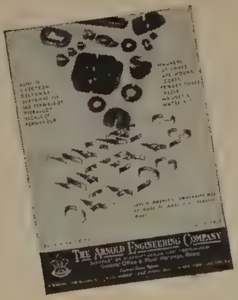




# Arnold Pulse Transformer Cores are individually tested under actual pulse conditions

W&D 5238


THE ARNOLD ENGINEERING COMPANY

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52 pages of valuable data covering a complete range of core shapes, sizes, tape gauges, etc.

**ADDRESS DEPT. P-12**

The inset photograph above illustrates a special Arnold advantage: a 10-megawatt pulse-testing installation which enables us to test-prove pulse cores to an extent unequalled elsewhere in the industry.

For example, Arnold 1 mil Silectron "C" cores—supplied with a guaranteed minimum pulse permeability of 300—are tested at 0.25 microseconds, 1000 pulses per second, at a peak flux density of 2500 gausses. The 2 mil cores, with a guaranteed minimum pulse permeability of 600, receive standard tests at 2 microseconds, 400 pulses per second, at a peak flux density of 10,000 gausses.

The test equipment has a variable range which may enable us to make special tests duplicating the actual operating conditions of the transformer. The pulser permits tests at .05, .25, 2.0 and 10.0 microsecond pulse duration, at repetition rates varying anywhere from 50 to 1000 pulses per second.

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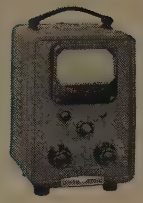
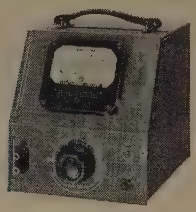
***for speed and accuracy***



### –hp– 410B Vacuum Tube Voltmeter

Wide range, flat response ± 1 db, 20 cps to 700 mc. Small, convenient, simple to use. Diode probe places approximately 1.5 $\mu\mu$fd capacity across circuit under test. This plus 10 megohms shunt impedance (high frequency) means circuits are not disturbed, and true voltage reading are assured. Also measures dc voltage to 1,000 volts and resistances to 500 megohms. $245.00.

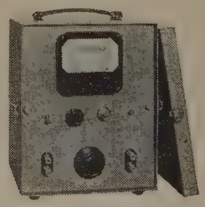


### –hp– 400A Vacuum Tube Voltmeter

Direct voltage readings between 10 cps and 1 mc. 30 millivolts sensitivity full scale; accuracy is ± 3% to 100 kc, ± 5% to 1 mc. Voltage range .005 to 300 volts. Input impedance 1 megohm shunted by 25 $\mu\mu$fd. $185.00.

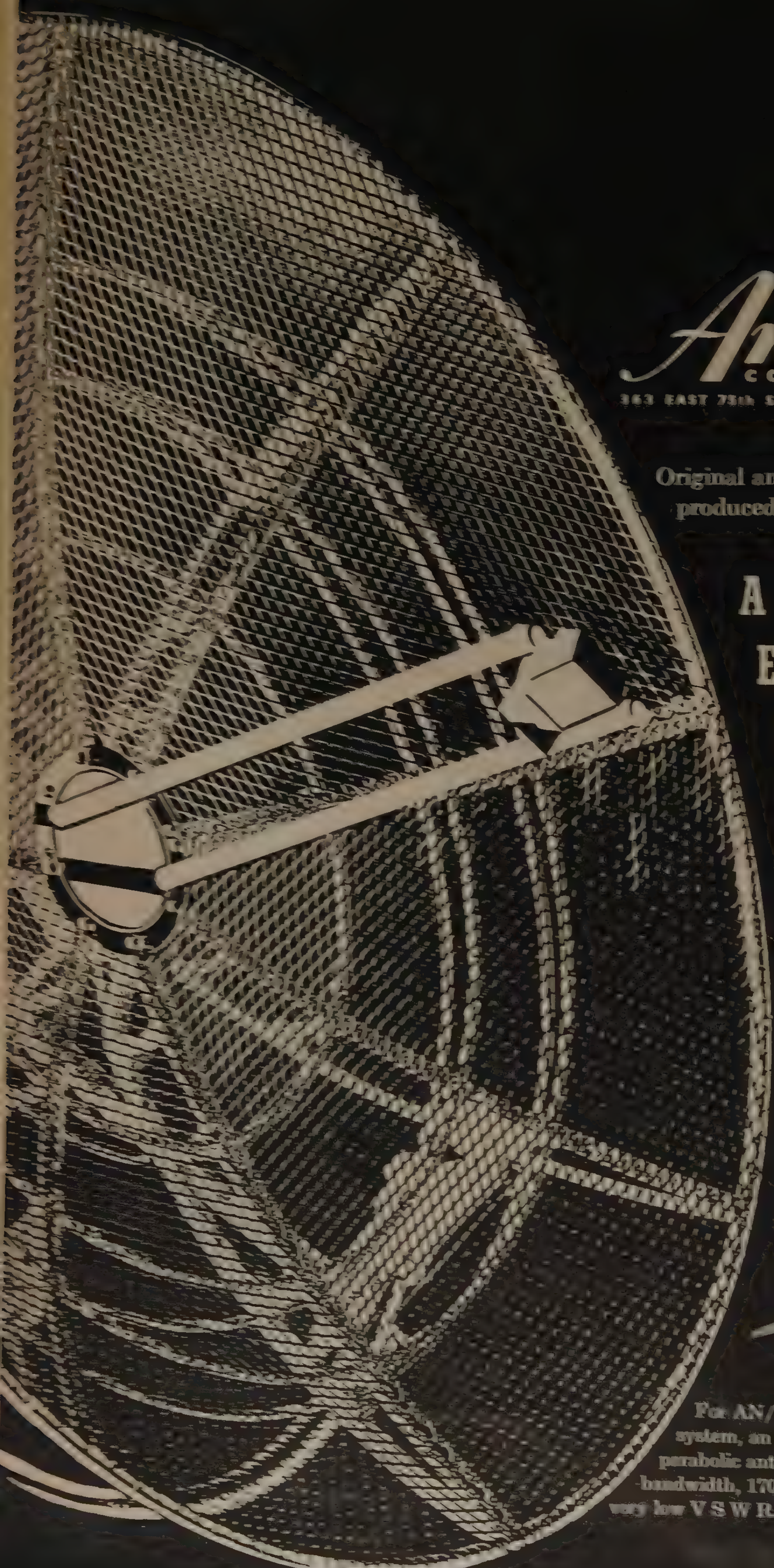
### –hp– 400B Vacuum Tube Voltmeter

For measurements 2 cps to 100 kc. Sensitivity 30 millivolts full scale. Measures voltage .005 to 300 volts, input impedance 9 megohms shunted by 25 $\mu\mu$fd. Accuracy ± 3% to 100 kc. Usable as stabilized amplifier. $195.00.



### –hp– 404A Battery-Operated Voltmeter

For general voltage measurements where ac power is not available. Compact, portable, splash-proof, ruggedly built. 2 cps to 50 kc, .0005 to 300 volts, impedance 10 megohms with 20 $\mu\mu$fd shunt. Ideal for remote broadcast, carrier, strain gauge, telemetering, geophysical work; completely hum free measurements. $185.00.



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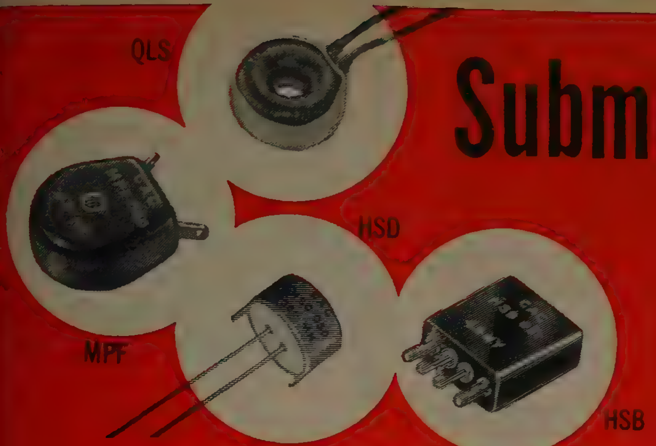

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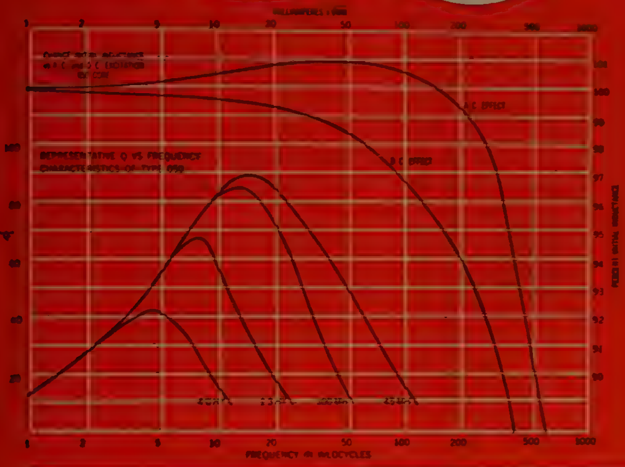

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Consistent with **advanced** engineering in subminiaturization, CAC offers transistor transformers in hermetically sealed cases, molded or cast type construction—designed to meet military requirements—temperatures (−) 55° C to (+) 105° C. Enclosed magnetic field afforded by toroidal form. Frequencies and impedances to your specifications . . . utilize our **advanced** engineering and modern high speed production facilities. See your CAC representative now.

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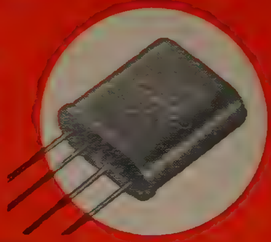
| IMPEDANCE RATIO | RISE TIME (MICRO SEC) | WIDTH (50% PEAK) | DROOP % PEAK | −OVERSHOOT % OF + PEAK | INPUT PULSE TIME MICRO SEC | RING |
|---|---|---|---|---|---|---|
| 200/800 | .3 | 8.1 | 10.4 | 0 | 8 | 3 |
| 700/2800* | .26 | 8.1 | 0 | 4.1 | 8 | 2.5 |
| 5000/2000 | 1.3 | 8.0 | 10.0 | 20.0 | 8 | 0 |

*Nominal Design



**A TYPICAL PULSE TRANSFORMER—ONE OF MANY CUSTOM DESIGNS DEVELOPED BY CAC ENGINEERS — HIGHLY STABLE TOROIDAL UNITS — EXHIBIT EXCELLENT CHARACTERISTICS**

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# Subminiature Filters

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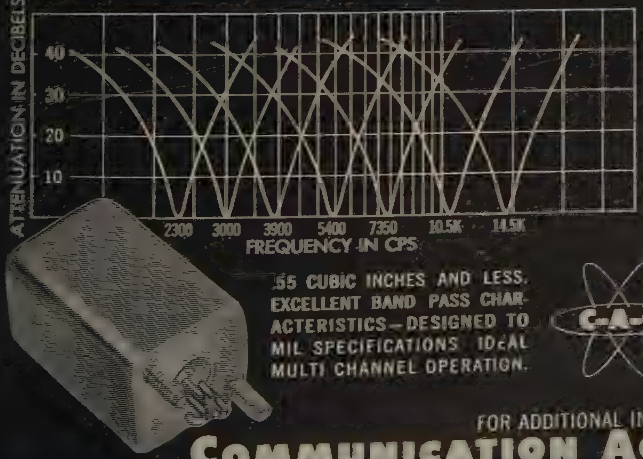

.55 CUBIC INCHES AND LESS. EXCELLENT BAND PASS CHARACTERISTICS—DESIGNED TO MIL SPECIFICATIONS. IDEAL MULTI CHANNEL OPERATION.

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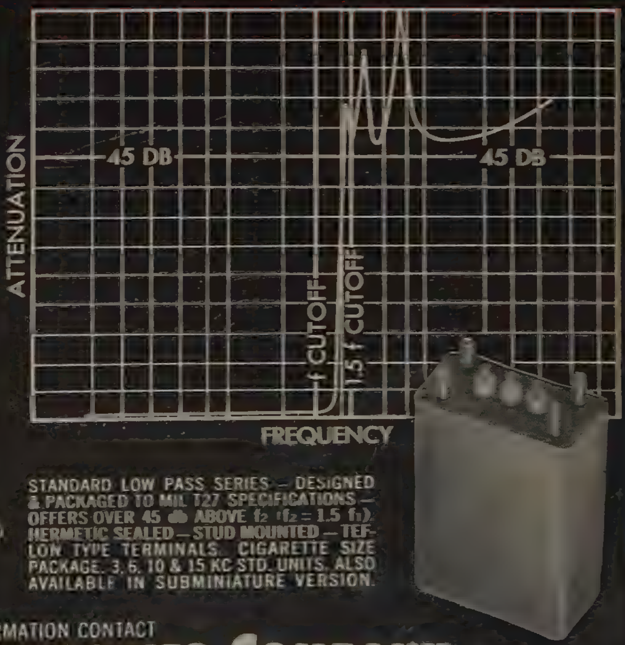

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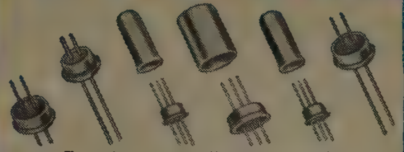
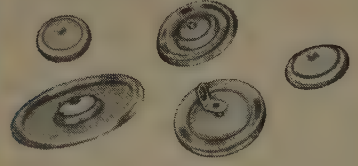
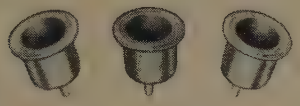


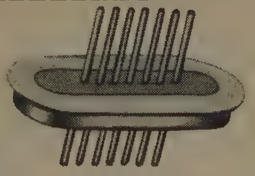
**1.** Transistor and diode assemblies available with cans



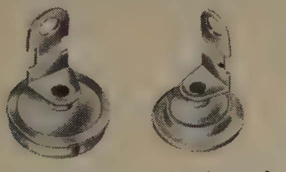
**2.** Strain-free end seals for condensers, resistors, tubular assemblies



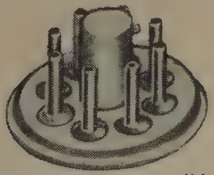
**3.** Single wire compression type miniature sealed terminals



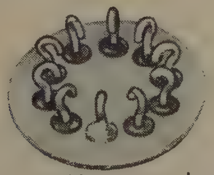
**4.** Miniature sealed header with cushioned glass construction



**5.** Lug type, lead thru insulators for voltages from 2,000 to 4,000 (rms.)



**6.** Octal headers with solid metal blanks for high mechanical strength



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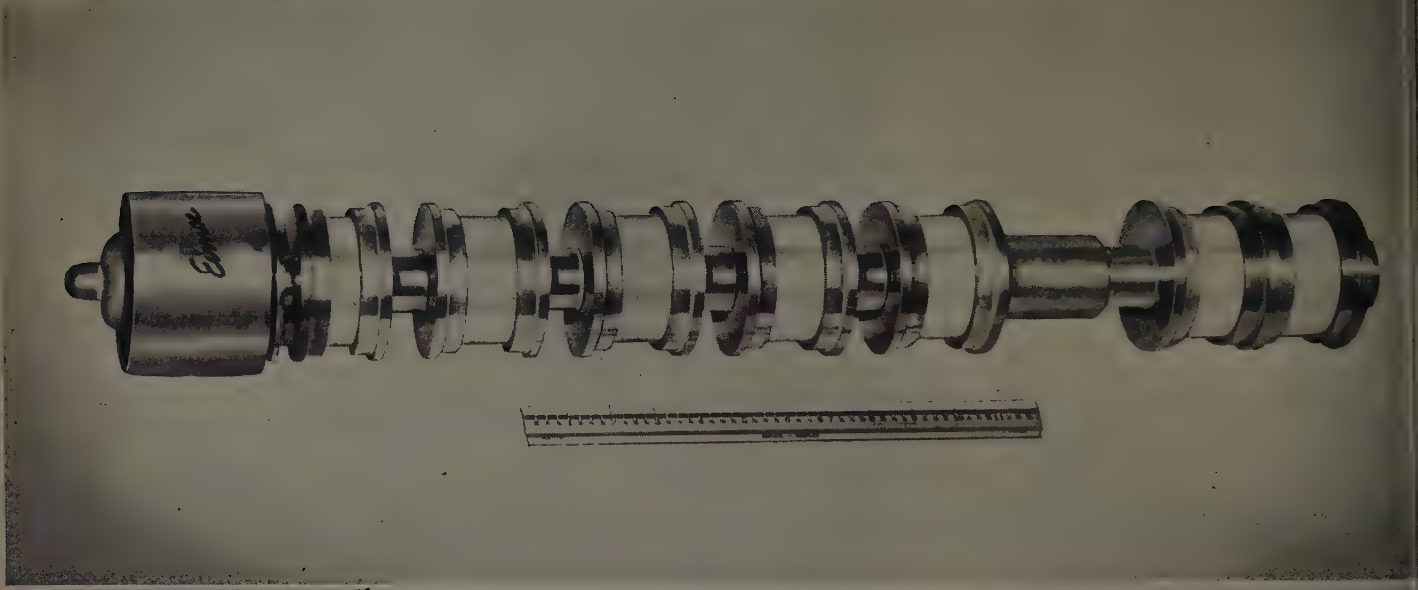
# Eimac Klystron Report

# X566

## 20kw modulating anode pulse klystron

**High power gain of 53db**

**UHF operation — 960-1400mc**



EIMAC X566 UHF klystrons have consistently obtained peak pulse power outputs of more than 20kw with over 40% efficiency at 960-1400mc. Many times more powerful than any other tube intended for similar operation, such as aircraft navigational aid Distance Measuring Equipment, the air-cooled X566 requires only 100 milliwatts driving power for a 20kw output — a power gain of 53db with bandwidth adequate for most pulse applications. Of special significance is the high average power capability of one kilowatt, allowing the duty cycle to be raised to 5% with a 20kw peak output, or 10% with 10kw output, and so on. Outstanding pulse capabilities of the X566 are made possible through the use of the Eimac modulating anode — an insulated anode between the cathode and drift tube section — permitting the klystron to be pulse modulated with
low pulsing power. In Eimac high power amplifier k
strons using ceramic and copper construction, the re
nant cavities are completed outside the vacuum syste
which is left free of RF tuning devices — permitti
easy wide range tuning and uncomplicated input a
output coupling adjustment. This simplicity of desi
and rugged construction minimize replacement co
as well as making the Eimac X566 suitable for m
production techniques.

The X566, another Eimac high power klystron achie
ment, is now available with circuit components for
perimental purposes.

- *For additional information, contact our Technical Services Department.*

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**PLUS** LFE's New PLUG-IN feature which greatly increases the number of applications which can be serviced by one instrument. More X-axis flexibility and unmatched versatility — at lower overall cost.

### *Specifications*

### X-AXIS PLUG-IN ADAPTERS

Model(s) 1400, BASIC, with 500 to 5000 cps trigger generator.
1401, SWEEP DELAY, continuously variable from 5 $\mu$ sec. to .1 sec.
1402, SWEEP EXPANSION, 5 to 1 expansion
1403, GATED MARKER GENERATOR, .1 $\mu$ sec. to .1 sec.
1404, TV TRIGGER SHAPER, triggers on composite video signal
1405, LONG SWEEPS, from 1 $\mu$ sec. /cm. to 10 sec. /cm.

### BASIC SCOPE

#### *Y-Axis Amplifier*

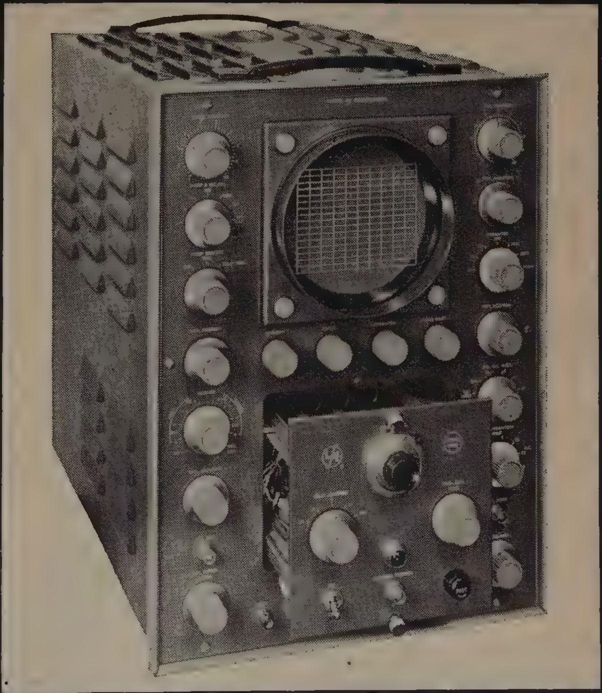
Deflection Sensitivity — 15 mv. /cm. p-p for both d-c and a-c (max.)
Max. Signal Voltage — 500 volts, peak.
Frequency Response — d-c to 10 mc /sec. (3 db point)
Transient Response — Rise time (10%-90%) — 0.035 $\mu$ sec.
Linearity of Deflection — Max. deflection, 5". At 2.5" unipolar deflection, maximum compression is 10%.
Signal Delay — 0.25 $\mu$ sec.
Input Termination — 53, 72, or 93 ohms.
Input Impedance — 1 megohm, 30 $\mu\mu$f.

#### *X-Axis*

Sweep Time Range, calibrated — .1 $\mu$ sec. /cm. to .1 sec. /cm
External Sweep Sensitivity — 2 volts /cm., p-p.
Frequency Response — DC to 1 Mc., (3 db. point)
Triggers — Internal or External to 10 mc., 60 cps
DC Blanking.

### OTHER FEATURES

Flat-face CRT Type 5-ABP1 (P7 or P11 optional) — Accelerating Potential 3000 or 4000 volts.
Deflection Plates Accessible.
Power Requirements: 105-125 V., or 210-250 V., 50-60 cycles. 385 watts.
Dimensions: 13" w. 17¾" h. 21" d.



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★ **GREATER FLEXIBILITY**—It corrects for fluctuations of the A-C input line voltage and can tolerate variations in the A-C frequency. Result: it can be used with portable and standby alternators as well as on utility lines.

★ **LESS CUBIC SPACE**—Designed for 19 inch relay rack mounting, with minimum panel height per KVA.

★ **LONGER LIFE**—Shut-downs are practically eliminated by the conservative design of all components and the inclusion of two voltage reference tubes—one used as an ever-ready alternate.

★ **LESS MAINTENANCE**—After the initial installation, no daily or weekly operating adjustments are required.

★ **MORE DEPENDABLE**—Provides a constant output voltage regardless of the fluctuations normally present in the input line.

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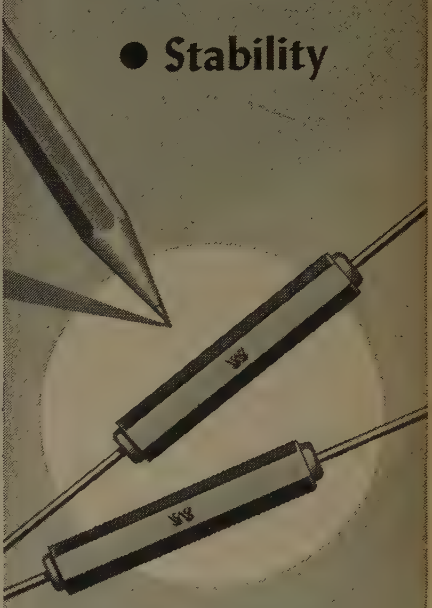
## ● Precision
## ● Stability



## S.S.White 65X MOLDED RESISTORS

**RATING**—1 watt.

**TEMPERATURE COEFFICIENT**—From approx. +0.1%/°F for 5000 ohm values to approx. −0.2%/°F for 10 megohm values.

**VOLTAGE COEFFICIENT**—Rated at less than 0.02%/Volt.

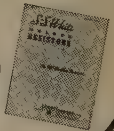
**UPPER TEMP. LIMIT**—170°F for continuous operation.

**NOISE LEVEL**—Low noise level inherent, but at extra cost we can test and guarantee standard range resistors with "less noise than corresponds to a resistance change of 1 part in 1,000,000 for the complete audio frequency range."

**VALUES**

Standard Range—1000 ohms to 9 megohms.

Extra High Value Range—Up to 10,000,000 megohms.



**BULLETIN 5409 has full details. Send for a copy. Attention Dept. GR.**

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G.E. offers experience and facilities to strengthen your competitive position . . . will analyze your circuit in terms of its specific tube requirements, and select the right types to give you optimum performance. You will receive every help in actually testing G-E tubes in your computer, from the time the latter is still in the "breadboard" stage.

Special computer tubes were pioneered by General Electric. G.E. is their largest builder. In line with performance requirements that become steadily more advanced, G.E. is devoting extensive research and development to still newer tubes for tomorrow's circuits—types that will be available for *you* when you need them.

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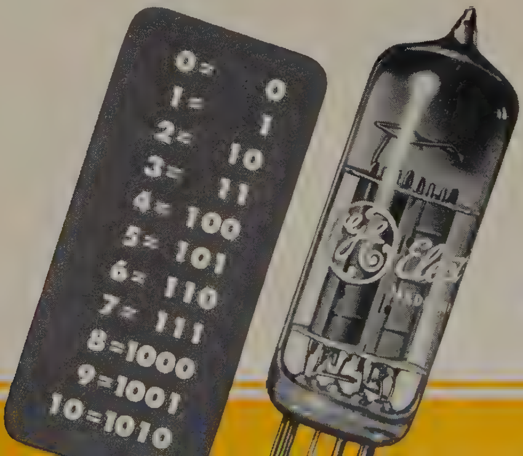
Most important of all, General Electric has ready . . . now . . . a line of special computer tubes for your immediate needs. They are described on the next page.



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# 5 SPECIAL G-E TUBES FOR COMPUTERS...
# DESIGNED FOR HIGH-SPEED CIRCUITS

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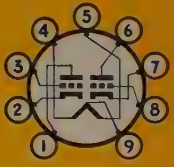
## GL-6463

9-pin high-capacity twin triode for extra-fast computers. Especially suited to frequency-divider circuits.

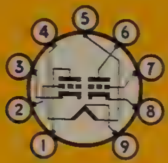
| | |
|---|---|
| Max cathode current, per section | 28 ma |
| Max dissipation, per plate | 4 w |
| Max tube dissipation | 7 w |
| Grid voltage required to cut off plate current | —11 v |
| Heater current | .6 amp |



## GL-6211

9-pin medium-mu twin triode for binary-counter or amplifier applications.

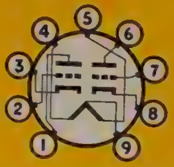
| | |
|---|---|
| Max cathode current, per section | 14 ma |
| Max dissipation, per plate | 1 w |
| Max tube dissipation | 2 w |
| Grid voltage required to cut off plate current | —10 v |
| Heater current | .3 amp |



## GL-5965

9-pin twin triode for high-speed computer use as binary-counter or amplifier tube.

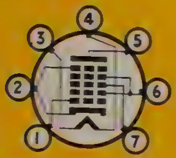
| | |
|---|---|
| Max cathode current, per section | 15 ma |
| Max dissipation, per plate | 2.2 w |
| Max tube dissipation | 4 w |
| Grid voltage required to cut off plate current | —5.5 v |
| Heater current | .45 amp |



## GL-5915-A

Dual-control heptode, for use primarily as a coincidence-gating tube.

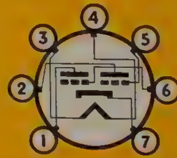
| | |
|---|---|
| Max cathode current | 20 ma |
| Grid voltage required to cut off plate current | —10 v |
| Typical plate current in gating service ("on" condition) | 5.8 ma |



## GL-5844

Medium-mu twin triode, for use as counter or amplifier tube in moderately high-speed computers.

| | |
|---|---|
| Max cathode current, per section | 9 ma |
| Max dissipation, per plate | .5 w |
| Max tube dissipation | 1 w |
| Grid voltage required to cut off plate current | —10 v |
| Heater current | .3 amp |



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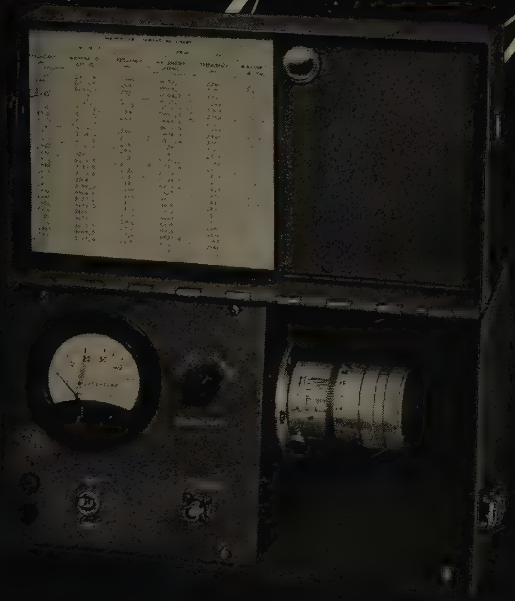
# Frequency Meters



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# FREQUENCY STANDARDS

These precision-built field test instruments were designed by Frequency Standards to provide rapid and accurate means of frequency measurement in the field. Frequency is determined by means of a micrometer dial. This reading is translated to frequency by accurate individual calibration charts or curves. Transducers, fittings, and cables can be supplied to meet the requirements of customers and convenient storage space for these items is provided in the lid of the instruments.

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|---|---|---|
| 912-4 | 900-1200 MC | .01% |
| 1217-4 | 1200-1700 MC | .02% |
| 1723-4 | 1700-2300 MC | .02% |
| 2335-4 | 2300-3500 MC | .02% |
| 3545-4 | 3500-4500 MC | .01% |
| 4458-4 | 4400-5800 MC | .01% |
| 5882-4 | 5800-8200 MC | .01% |

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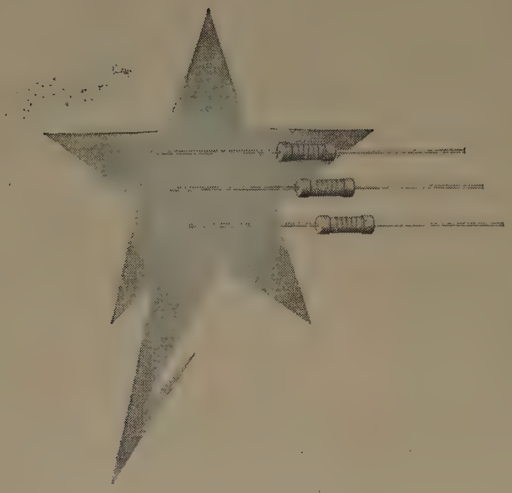

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A trial will convince you why they are now preferred by many outstanding electronic design engineers, and why you should always make your choice Noblette ½, 1 and 2 watt with axial leads or Nobleloy ½, 1, 2 & 5 watt with radial leads.

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For low power application. Composed with a minimum of .0015 inch wire that is wound automatically for true parallel winding to prevent shorting at turns. Terminals are securely bonded to permanent connections to the winding. They are moisture resistant and recommended for circuits requiring very low resistance, which is not ordinarily available in the carbon style. (Write for technical data and catalog on all Continental products.)

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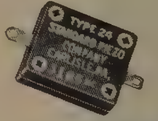

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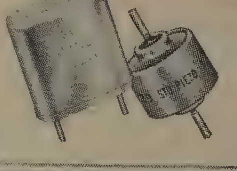

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**PRD**

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- NEGLIGIBLE INSERTION LOSS
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PRD precision variable attenuators have long been recognized for their outstanding constancy of attenuation with time as well as for their insensitivity to variations of humidity and temperature.

Since the inception of the art of placing metal films on glass or mica to provide attenuation at microwave frequencies—over ten years ago—PRD has consistently maintained its leadership in this field. From simple level set attenuators to the most precise secondary standards, PRD offers the most complete line available—covering the entire range from 2,600 to 40,000 mcps.

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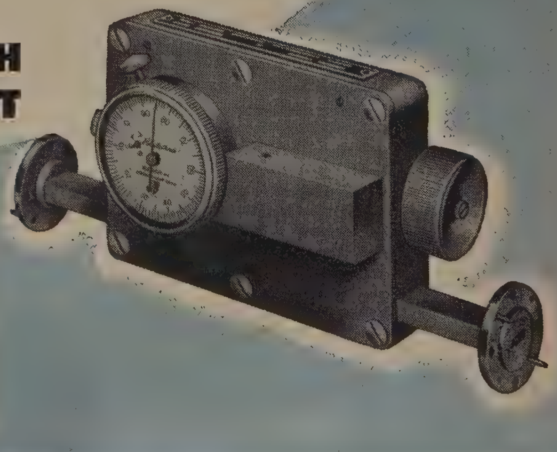
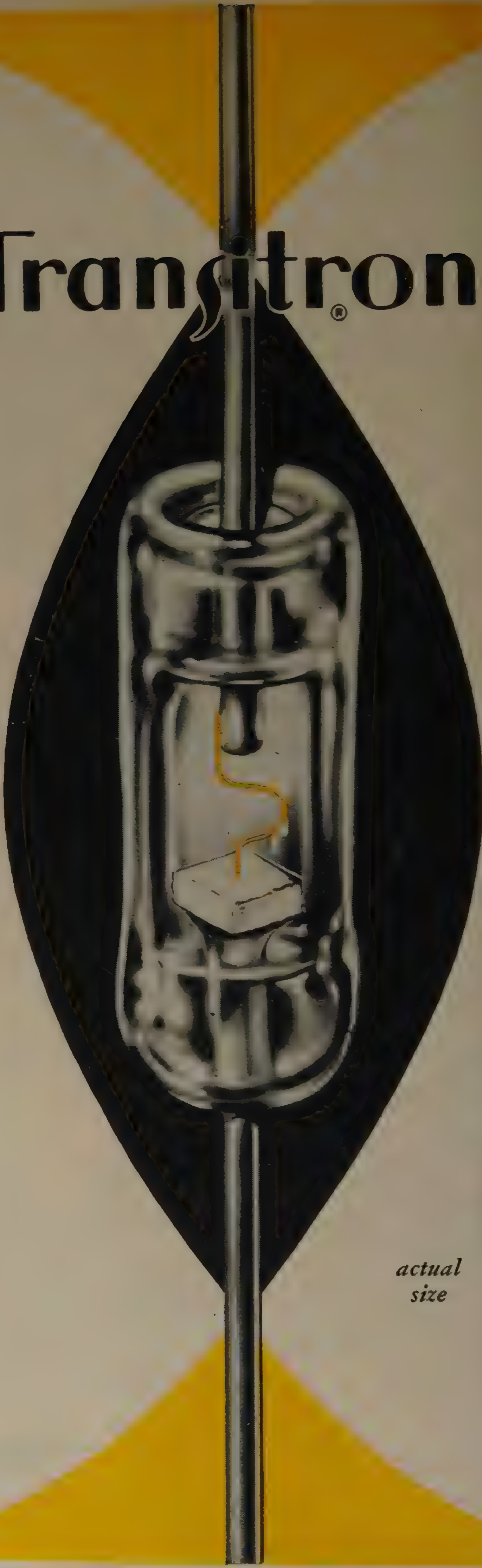


NOW . . . FROM **Transitron**®

AN OUTSTANDING
ADVANCE IN
SUBMINIATURE
GLASS DIODES



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**GOLD BONDED CONSTRUCTION**

which gives superior electrical characteristics has been combined by Transitron with hermetic sealing in glass to produce a subminiature diode with unsurpassed performance.

These diodes offer the following advantages:

- SUPERIOR FORWARD CONDUCTANCE
- HIGHER INVERSE RESISTANCE
- GREATER RUGGEDNESS
- MORE UNIFORM CHARACTERISTICS
- GREATER POWER HANDLING
- COMPLETE RELIABILITY

All Transitron diodes must pass rigid tests, including shock, vibration, and temperature and humidity cycling between +135°C and −78°C. Strict conformance to all specifications is insured through 100% final electrical testing.

T® *"The MARK of Quality in Electronics"*

## WHAT IS GOLD BONDING?

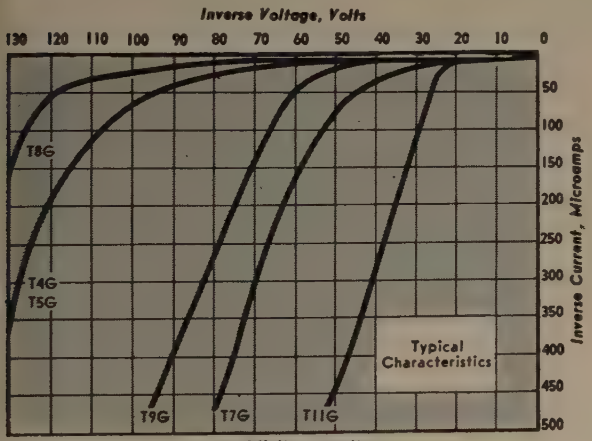
Gold bonding is a process in which a gold whisker is alloyed by low temperature fusion to germanium. At the contact point both the whisker tip and the germanium are melted to form a eutectic alloy. This results in a rectifying subminiature P-N junction. Because the gold wire is dead soft, pressure cannot be transmitted, and mechanical isolation of the junction is achieved. Permanent electrical and mechanical stability is thus assured.

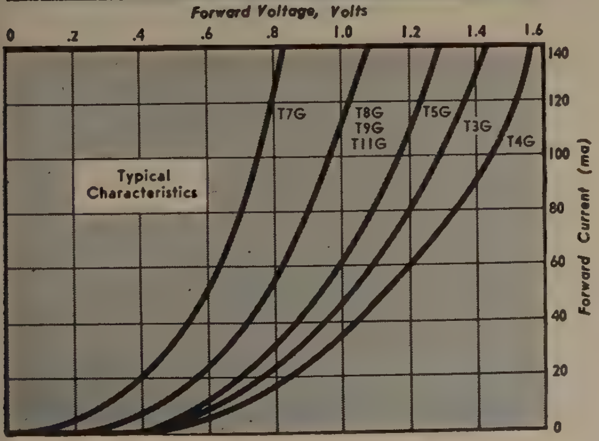
In contrast, the point contact "welded" diode uses a firm whisker wire such as tungsten or platinum ruthenium which does not alloy with the germanium in the forming process. Therefore, rectification depends upon the pressure of the whisker on the germanium. Variations in this pressure can cause variations in diode performance.

## WHY ARE GOLD BONDED DIODES BETTER?

***Electrically they are many times superior.*** The subminiature P-N junction formed at the bond provides electrical characteristics that approach those of an ideal diode. The typical Transitron diode offers forward conductance averaging more than five times higher than point contact types. In addition, types such as the T8G feature more than 100 milliamperes forward at +1 Volt, and over 5 megohms at —100 Volts inverse.

***Mechanically they are more rugged.*** The eutectic alloy bond between the gold whisker and the germanium has a strength that is equal to that of the whisker itself. It is virtually impossible to affect the performance of these diodes by shock or vibration.

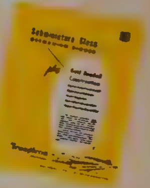




## HIGH CONDUCTANCE DIODES

SPECIFICATIONS (At 25°C except as noted)

| TYPE | Forward Current at +1V (ma Min.) | Inverse Current at Specified V (ua Max.) | Max. Inv.† Voltage (Volts) | DESCRIPTION |
|---|---|---|---|---|
| T7G | 200 | 100 @ -50V | 75 | 200 MA TYPES |
| T25G | 200 | 20 @ -10V | 25 | |
| T8G | 100 | 20 @ -100V<br>5 @ -10V | 125 | 100 MA TYPES |
| T9G | 100 | 20 @ -50V<br>2 @ -10V | 75 | |
| T11G | 100 | 20 @ -20V | 35 | |
| T6G | 100 | 200 @ -20V | 35 | |
| T5G | 40 | 100 @ -100V | 125 | 40 MA TYPES |
| 1N100A | 40 | 50 @ -50V<br>5 @ -5V | 100 | |
| 1N98A | 40 | 100 @ -50V<br>8 @ -5V | 100 | |
| 1N118A | 40 | 100 @ -50V | 75 | |
| T2G | 40 | 300 @ -50V | 75 | |
| T13G | 40 | 2 @ -10V | 25 | |
| T14G | 40 | 5 @ -10V | 25 | |
| 1N99A | 20 | 50 @ -50V<br>5 @ -5V | 100 | 20 MA TYPES |
| T3G | 20 | 50 @ -50V | 75 | |
| 1N97A | 20 | 100 @ -50V<br>8 @ -5V | 100 | |
| 1N117A | 20 | 100 @ -50V | 75 | |
| T12G | 20 | 500 @ -50V<br>30 @ -10V | 75 | |
| **HIGH RESISTANCE DIODES** | | | | |
| 1N55B | 5 | 500 @ -150V | 190 | 100 VOLT TYPES |
| T8G | 100 | 20 @ -100V<br>5 @ -10V | 125 | |
| T5G | 40 | 100 @ -100V | 125 | |
| T4G | 5 | 100 @ -100V | 125 | |
| T9G | 100 | 20 @ -50V<br>2 @ -10V | 75 | 50 VOLT TYPES |
| 1N67A | 5 | 50 @ -50V<br>5 @ -5V | 100 | |
| T3G | 20 | 50 @ -50V | 75 | |
| T11G | 100 | 20 @ -20V | 35 | 20 VOLT TYPE |
| T13G | 40 | 2 @ -10V | 25 | 10 VOLT TYPES |
| T14G | 40 | 5 @ -10V | 25 | |
| 1N128 | 5 | 10 @ -10V | 50 | |
| **HIGH TEMPERATURE DIODES** | | | | |
| T18G | 20 | 125 @ -50V | 50 | ALL SPECIFICATIONS AND RATINGS ARE AT 75°C<br>(T20G at 75°C is electrically equivalent to 1N34A at 25°C) |
| 1N198 | 5 | 250 @ -50V<br>75 @ -10V | 50 | |
| T19G | 200 | 180K avg. @ 40V RMS | 40V RMS | |
| T20G | 20 | 500 @ -50V<br>30 @ -10V | 50 | |
| T21G | 20 | 50 @ -20V | 25 | |
| T22G | 40 | 20 @ -10V | 15 | |
| T23G | 20 | 200 @ -50V‡ | 50 | ALL SPECIFICATIONS AND RATINGS ARE AT 60°C |
| T24G | 20 | 300 @ -30V‡ | 35 | |
| **COMPUTER DIODES** | | | | |
| T15G | 125 | 500K between -20 and -90V | 125 | Inverse Recovery Time Tested. |
| T16G | 40 | 500K between -10 and -50V | 75 | Forward and Inverse Recovery Time Tested. |
| 1N191 | 5 | 400K between -10 and -50V @ 55°C ‡ | 75 | Inverse Recovery Time Tested. |
| 1N192 | 5 | 200K between -10 and -50V @ 55°C ‡ | 75 | Inverse Recovery Time Tested. |
| T7G | 200 | 100 @ -50V | 75 | LOW IMPEDANCE FAST FORWARD SWITCHING TIME.<br>(These types are particularly useful for magnetic core switching) |
| T25G | 200 | 20 @ -10V | 25 | |
| T11G | 100 | 20 -20V | 35 | |
| T6G | 100 | 200 @ -20V | 35 | |
| **JAN TYPE DIODES** | | | | |
| 1N126 | 5 | 800 @ -50V<br>50 @ -10V | 75 | *The above is a partial list of available types. Send for complete details in Bulletin E1319.* |
| 1N127 | 5 | 300 @ -50V<br>25 @ -10V | 125 | |
| 1N128 | 5 | 10 @ -10V | 50 | |
| 1N198 | 5 | 250 @ -50V<br>75 @ -10V<br>at 75°C | | |



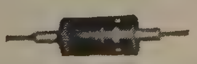
ADDITIONAL SPECIFICATIONS

| | |
|---|---|
| Ambient Temperature Range | -78°C to +90°C |
| Absolute Maximum Storage & Handling Temperature Range | -78°C to +150°C |
| Avg. Power Dissipation @ 25°C | 80 Milliwatts |
| Derating above 25°C | 10mw/10°C |
| Average Shunt Capacitance | 0.5 uufd |

† Measured at 0.1 Watt

‡ Measured with 60 CPS sweep.

**Transitron** electronic corporation • melrose 76, massachusetts

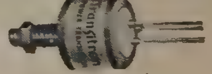


Germanium Diodes

Transistors

Quads

Silicon Diodes



Power Transistors

# New!

# LAMBDA MODEL 71 PORTABLE POWER SUPPLY

**WIDE RANGE!** 0-500 VDC @ 0-200 MA

**LIGHT!** Weighs only 49 lbs.

**COMPACT!** 13" high, 8¾" wide, 14½" deep

A de luxe unit that combines every good engineering feature with maximum compactness and portability.

$289⁵⁰ F.O.B. Factory, Corona, N. Y.

**A VERSATILE, HEAVY-DUTY PORTABLE WITH BROAD FIELD AND LABORATORY APPLICATIONS**

Cannot be damaged by external overloads! No down time! Circuit breakers provide complete protection!

## SPECIAL FEATURES

- Overload Circuit Breakers. AC and DC Circuit Protection
- No "Down Time" due to External Overloads
- Stable 5651 Reference Tube
- Vernier High Voltage Control
- Hermetically-Sealed, Oil Filled Condensers
- Time Delay Tube Protection
- All-Aluminum Construction
- Made by America's Leading Power Supply Specialists

## SPECIFICATIONS FOR LAMBDA MODEL 71 PORTABLE

**INPUT**..........105-125 VAC, 50-60 CPS, 475 W (max)

**DC OUTPUT NO. 1** (regulated for line and load)
Voltage..........0-500 VDC (continuously variable)
Current..........0-200 MA (over entire voltage range)
Regulation (line)....0.15% or 0.3 volt (whichever is greater)
Regulation (load)....0.15% or 0.3 volt (whichever is greater)
Internal Impedance..........Less than 4 ohms
Ripple and Noise..........Less than 5 millivolts rms
Polarity..........Either positive or negative may be grounded

**DC OUTPUT NO. 2** (regulated for line only)

| Voltage ranges: | Internal Impedances: |
|---|---|
| (a) 0-50 VDC (no load) | 5,500 ohms |
| (b) 0-200 VDC (no load) | 25,000 ohms |

Current range:
Any value of external load impedance may be used including continuous low impedance or short-circuit. Insignificant inter-action on Output No. 1 Short Circuit Current: 9 MA (Max.)
Regulation (line)..........Better than 0.1%
Ripple and Noise..........Less than 5 millivolts rms
Polarity..........Positive terminal connected internally to negative terminal of DC Output No. 1.

**AC OUTPUTS** (unregulated)
Two outputs, isolated and ungrounded. Each is 6.5 VAC at 5A (at 115 VAC input). Allows for drop in connecting leads. May be connected in series for 12.6V (nominal) at 5A, or in parallel for 6.3V (nominal) at 10A.

**AMBIENT TEMPERATURE AND DUTY CYCLE:**
Continuous duty at full load up to 40°C (104°F) ambient.

**OVERLOAD PROTECTION:**
External overload protection..........AC and DC magnetic circuit breakers. Trip-Free. Instant manual reset. Front panel.
Internal failure protection..........Fuses, access through rear of cabinet.

**INPUT AND OUTPUT CONNECTIONS:**
Input..........8 foot heavy duty rubber covered line cord with integral molded plug, rear of cabinet.
Output..........Sturdy insulated "5-way" binding posts, front panel.

**METERS:**
Output voltage..........Multi-range 3½" rectangular voltmeter calibrated 0-50 VDC, 0-200 VDC, 0-500 VDC.
Output current..........3½" rectangular milliameter calibrated 0-200 MA.

**VOLTAGE REFERENCE TUBE:**
A stable 5651 reference tube is used to obtain superior long-time voltage stability.

**TIME-DELAY RELAY CIRCUIT:**
A 30 second time delay circuit is provided to allow tube heaters to come to proper operating temperature before high voltage can be applied.

**SIZE AND WEIGHT AND FINISH:**
Size..........13" H x 8¾" W x 14½" D
Weight..........49 lbs.
Finish..........Two-tone gray

**LAMBDA Electronics Corp.**

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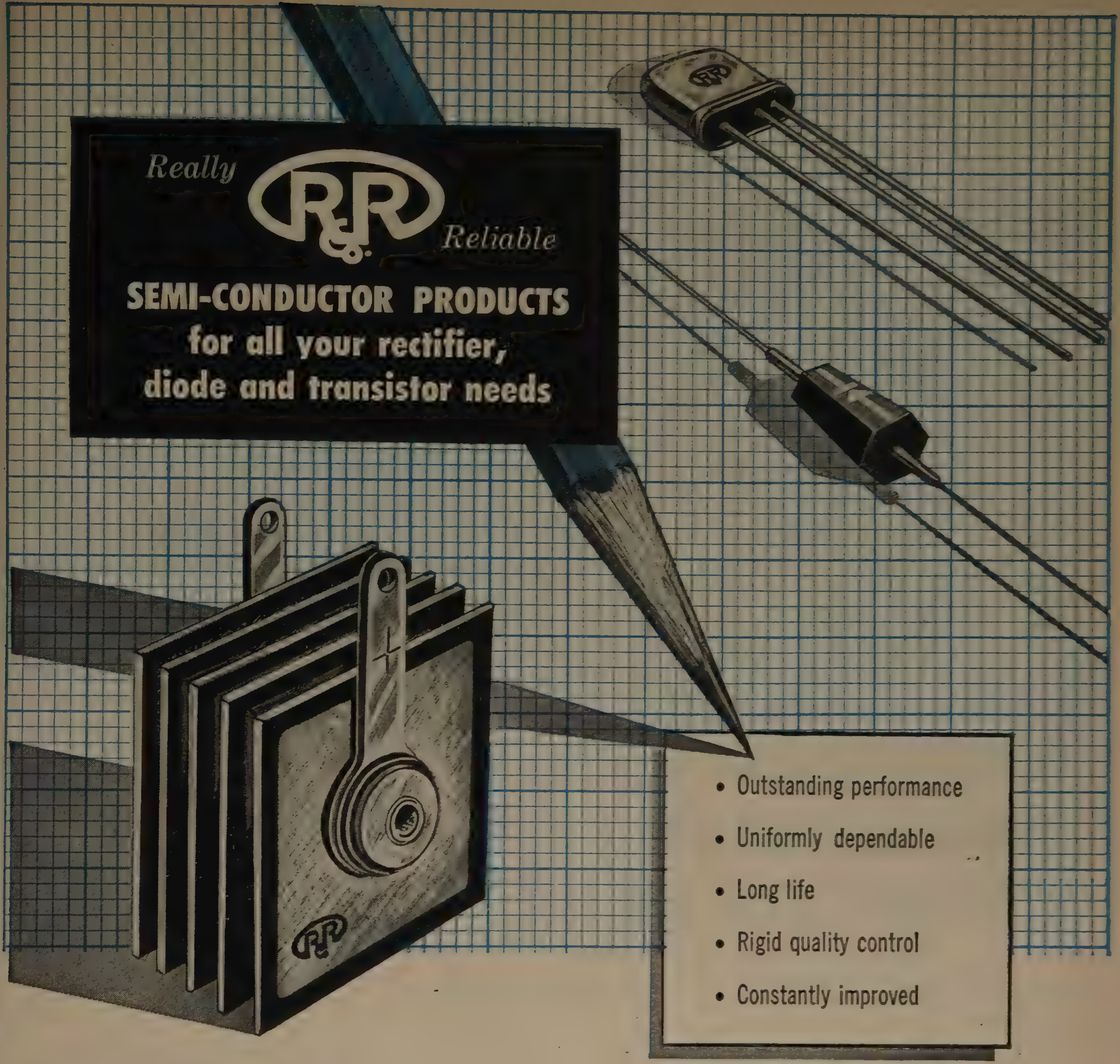
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SEMI-CONDUCTOR PRODUCTS
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diode and transistor needs
• Outstanding performance
• Uniformly dependable
• Long life
• Rigid quality control
• Constantly improved

RADIO RECEPTOR CO. conducts continuing laboratory research to maintain highest standards for existing types of selenium rectifiers, silicon and germanium diodes and transistors—and to develop new units, including those to meet special needs where necessary.

As rapidly as possible we publish bulletins on our products and they are always available upon request. Sometimes, though, we find the printing presses simply cannot keep up with our progress . . . So, for the best and most up-to-date facts about RADIO RECEPTOR semi-conductor products *we suggest you submit your specifications.* Our engineers will gladly make recommendations incorporating the very latest information at their command. Just address Section P-2.

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Longer Shelf Life

**Fansteel**

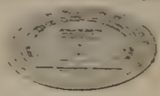
# TANTALUM CAPACITORS

Electrically proven in every way, and over a twenty year period, there's really nothing "new" about tantalum capacitors except in the significantly increased demand for them, and the continually expanding list of their applications.

Incorporating a porous tantalum anode assembly, tantalum capacitors derive their unusual stability from the characteristics inherent in tantalum itself—the most stable of *all* anodic film forming metals. It has been observed consistently that no important changes of characteristics occur in long periods of operation; there is no shelf aging. Large capacity in extremely small size is also an important advantage.

The growing demand for Tantalum Capacitors is being adequately met by Fansteel and other leading manufacturers. Write for current technical bulletins.

NEW...
**Power Factor Slide Rule**
All plastic, 8" circular rule gives power factor of capacitors from 0.06 to 10,000 mfd., at a glance.



Send a dollar bill with your letterhead to cover partial cost of rule, postage and handling. No C.O.D.s or charges, please.

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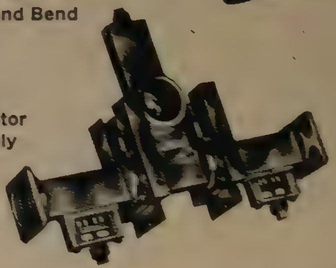
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**We are staffed to design to your specifications or manufacture to your drawings. Supporting this engineering and manufacturing capacity is a completely equipped Electrical Testing Laboratory utilizing the finest in Testing Techniques. Technicraft also has a complete line of flexible waveguides and test components.**

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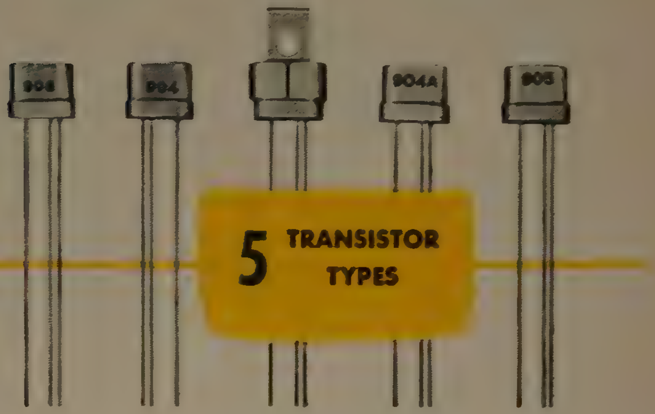
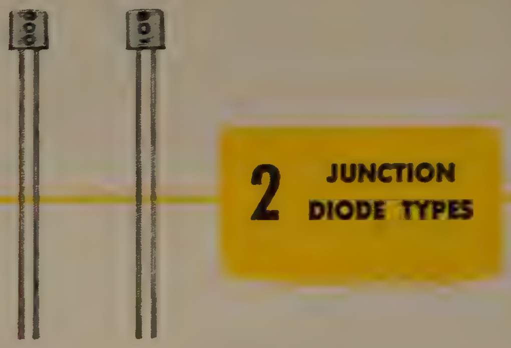
# quantities

**HIGH VOLUME PRODUCTION** of *silicon* semiconductor devices enables Texas Instruments to offer you an enlarged line of five types of silicon transistors and two types of silicon junction diodes . . . all available for immediate delivery in production quantities!



**SILICON TRANSISTORS**-produced commercially by and available *only* from Texas Instruments – are now available with alpha (current amplification factor) to over 0.975 and with alpha cutoff frequency to over 8 megacycles . . . stable to 150° Centigrade (302° F)!



**SILICON JUNCTION DIODES** are also manufactured by Texas Instruments from grown single crystals and feature back currents as low as 0.001 microamp and safe operation to 150° Centigrade! All TI semiconductor devices – *silicon* or germanium; diodes, triodes and tetrodes – are made with glass-to-metal hermetic seals.

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Standard and special duplexers, from 6.66 x 3.41 to .360 x .220 O. D. Power, performance and packaging to meet your applications. *Bulletin T-2200.*

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4 basic types in all waveguide sizes from 6.66 x 3.41 to .360 x .220 O. D. Broadband couplings and directivities to meet your needs. *Bulletin T-2400.*

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Precision castings, holding tolerances of ±.002" per inch of dimension, economically made to your own specifications. *Bulletin 6002.*

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Available in all sizes for high power pressurized applications over wide temperature ranges. Seamless, twistable, preformed and circular. Special waveguides to meet specific problems. *Cat. 1011*

**TWO-POSITION WAVEGUIDE SWITCHES**
For rapid and/or cyclic switching to or from noise sources, signal generators, dummy loads, etc. Low VSWR, excellent crosstalk and high peak power performance. *Cat. 2331.*

**SHORT SLOT HYBRIDS**
Precision cast one piece hybrids. Low VSWR, excellent isolation and low attenuation over broad bandwidths. Used in balanced mixers, duplexers, power splitters. *Cat. 2361.*

**K-BAND TEST HORNS**
For test purposes over the frequency range from 12,400 to 40,000 mc. One piece aluminum castings to close tolerances. Low VSWR. Low secondary lobes. *Cat. 3291.*

**WAVEGUIDE MAGIC TEES**
Hybrid junctions for power splitting with minimum energy loss. From 3.00 x 1.50 to all smaller standard and military sizes. Low VSWR and excellent broadband isolation. *Cat. 3330*

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# Plan Now for the 4 biggest days in radio-electronics!

# I R E National Convention and RADIO ENGINEERING SHOW

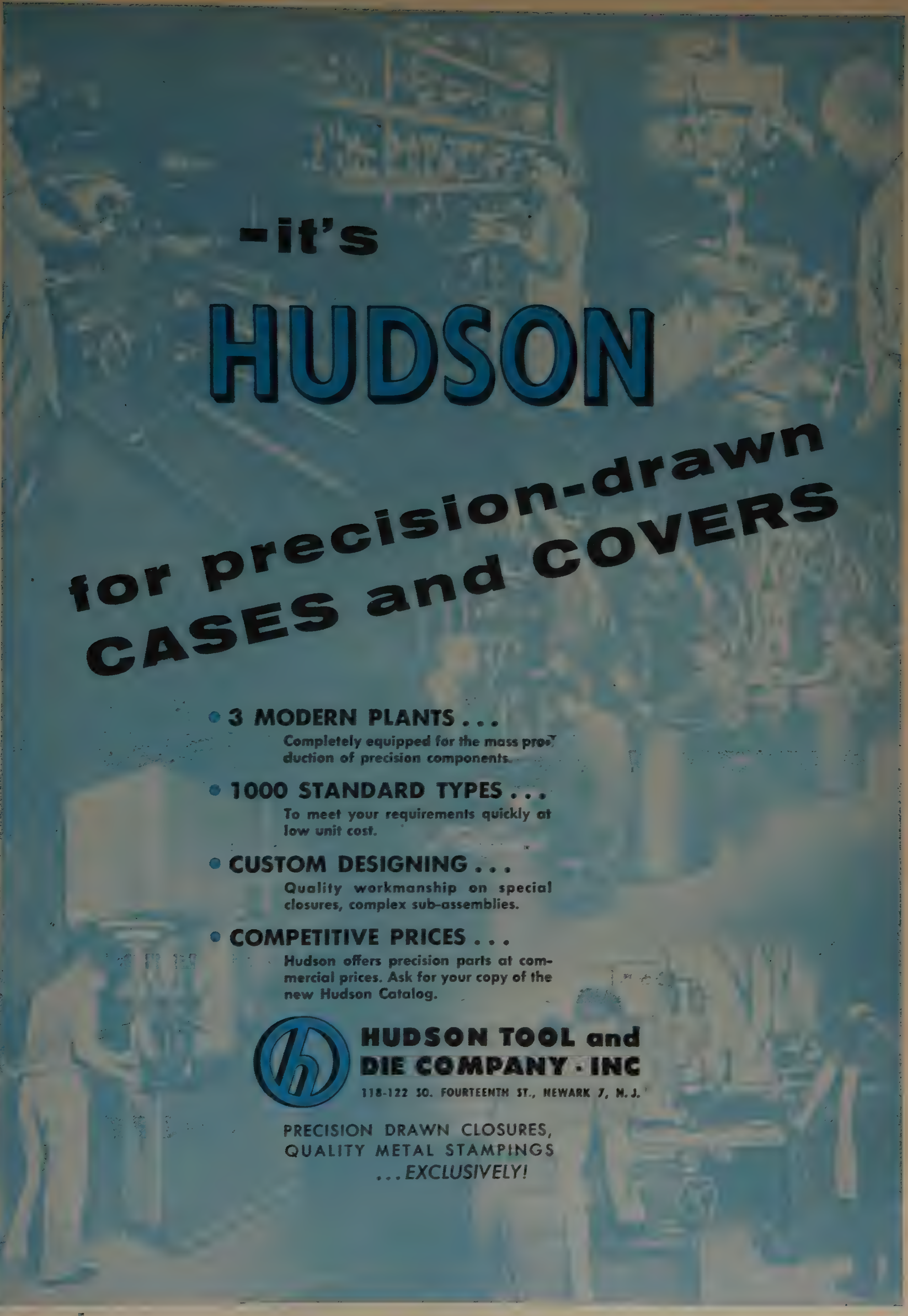
**March 21-24**
**New York City**

Once again, you'll soon have the opportunity of appraising all of the important new developments of the past year in radio and electronics. In 4 days, from March 21 through 24, the I R E National Convention and Radio Engineering Show will give you the complete picture of significant developments in the industry achieved during the past year.

***You'll hear*** the presentation of scientific and engineering papers of vital interest to you, carefully arranged into related groups of technical sessions.

***You'll see*** more than 700 exhibits in a 4-acre panorama of all that's new in the radio and electronics field, at Kingsbridge Armory and at Kingsbridge Palace.

The Institute of Radio Engineers
1 East 79th Street,
New York City



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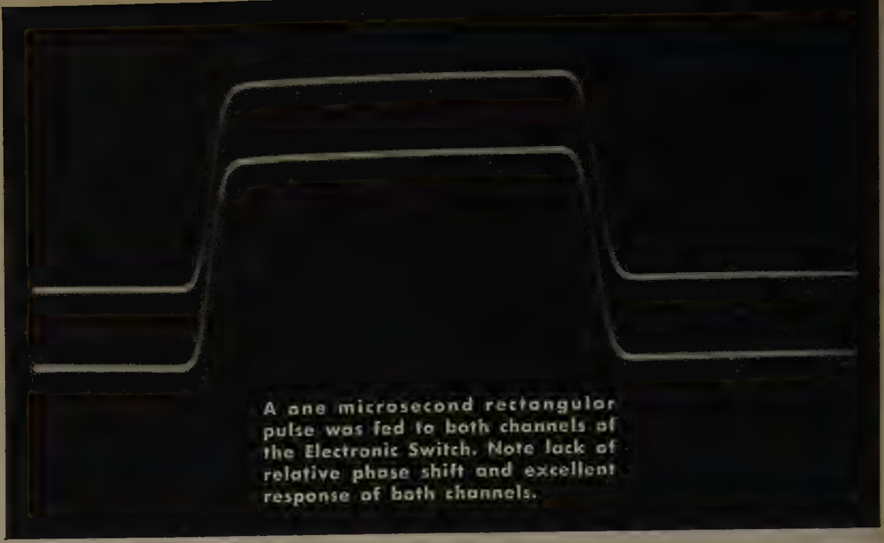
QUALITY METAL STAMPINGS
. . . *EXCLUSIVELY!*

## Convert to Dual Channel Operation in the Range of DC to 15 MC



A one microsecond rectangular pulse was fed to both channels of the Electronic Switch. Note lack of relative phase shift and excellent response of both channels.

*...using any Single-Channel Oscillograph*

*with the*

# NEW DU MONT
# TYPE 330 ELECTRONIC SWITCH

The new Du Mont Type 330 Electronic Switch is a self-contained accessory for oscillography that permits . . .

1. Converting *any* single-beam oscillograph into a dual-channel instrument.
2. Adding a channel to any multi-channel instrument.
3. As a chopper, converting an a-c oscillograph for d-c measurement.

Within the range of DC to 15 MC, the Type 330 is limited only by the characteristics of the cathode-ray oscillograph being used.

This is the answer to those studies requiring comparison between two or more functions. Maximum time shift between the channels of the Type 330 is within one millimicrosecond. Both channels may be adjusted for unity gain making it a simple matter to superimpose two phenomena for very precise time, phase or amplitude comparison.

Three free-running switching rates, 1KC, 10KC and 100KC, or triggered operation allow selection for best presentation on the cathode-ray oscillograph. The Type 330 can be connected into a test setup or disconnected as the need arises.

### MAJOR SPECIFICATIONS

SIGNAL CHANNELS

I. Sinusoidal Frequency Response: with an output load of 60 uuf, either channel, flat to d.c. and down not more than 3 db at 15 mc.

II. Amplifier Rise Time: with external load of 60 uuf, no greater than 0.022 usec.

III. Variable Attenuator: Each channel has two series stepped attenuators with attenuation ratios of 1, 2, 4, 10, 20, 40, 100, 200, and 400; accuracy of attenuators ± 2%.

IV. Output: Level is zero volts d.c. with no signal or positioning voltage; positioning controls provide ±1 volt of d.c. positioning voltage.

SWITCHING

I. Recurrent: Free-running, fixed frequencies of approximately 1 KC, 10 KC and 100 KC; Triggered, rate may be triggered at 0 to 100 KC rates.

PRICE **$295**

**WRITE FOR COMPLETE INFORMATION**

**DU MONT**

**ALLEN B. DU MONT LABORATORIES, INC.**
**INSTRUMENT DIVISION**
**760 BLOOMFIELD AVENUE • CLIFTON, N. J.**

# FOR ALL Ku-BAND APPLICATIONS SPECIFY THE FINEST KLYSTRON...

## VARIAN'S NEW VA-94

Varian now offers the most advanced reflex klystron ever developed for airborne radar local oscillator and beacon service. *The VA-94* provides a minimum power output of 20 mw throughout its range of 16 to 17 kmc . . . to give you absolutely reliable operation at any altitude without pressurization.

Exclusive Varian features include a unique brazed-on external tuning cavity . . . to assure you of excellent frequency stability, extremely low microphonics, slow tuning rate and long tuning life. Its single screw tuner adapts easily to motor tuning. The VA-94 weighs only four ounces and mates directly with standard waveguide flanges.

*TYPICAL OPERATION*

| | |
|---|---|
| *Frequency* | *16.5 kmc* |
| *Resonator Voltage* | *300 v* |
| *Resonator Current* | *38 ma* |
| *Reflector Voltage* | *– 150 v* |
| *Power Output (VSWR < 1.1)* | *40 mw* |
| *Electronic Tuning* | *65 mc* |

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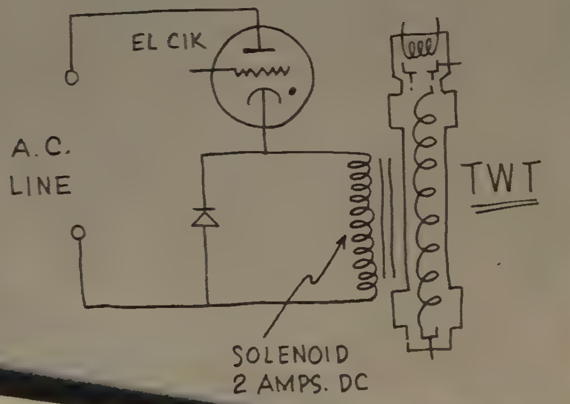

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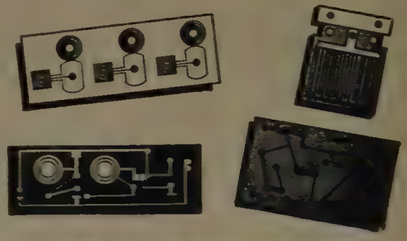

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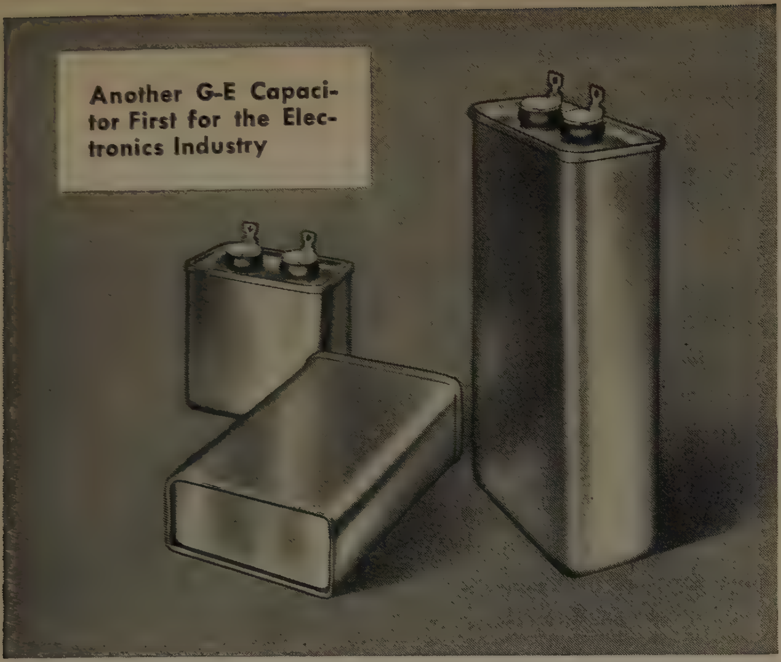

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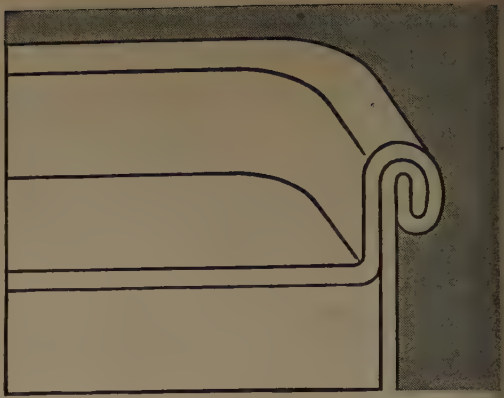
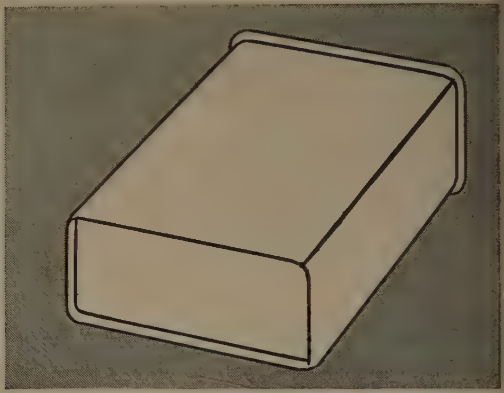
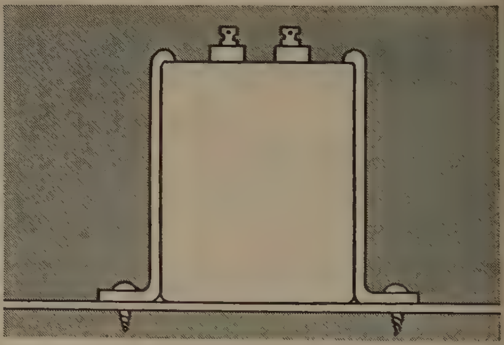


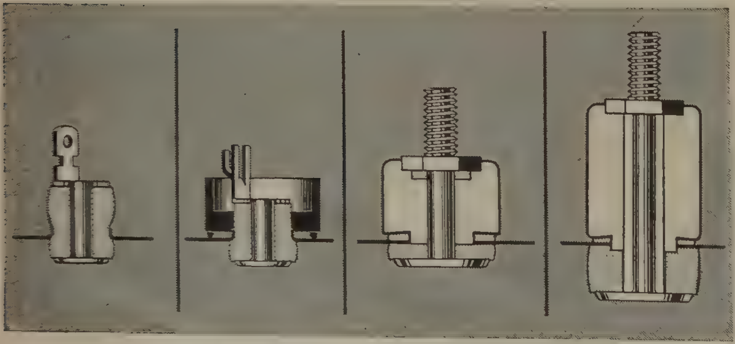
**SOLDERLESS DOUBLE-ROLLED COVER SEAM** makes a mechanically strong, hermetic seal.



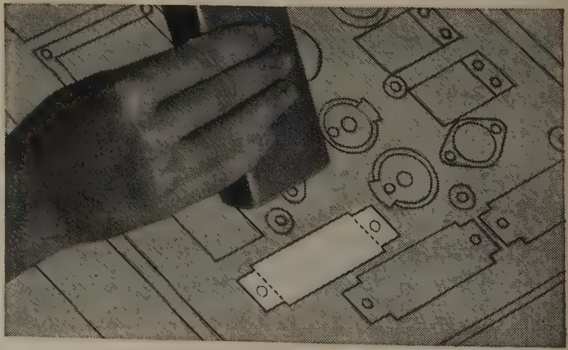
**BOTTOM OF CASE IS INDENTED** to permit mounting in inverted position.



**UPRIGHT OR INVERTED MOUNTING** is possible using either spade lug, or footed brackets (above)



**FOUR BUSHINGS STYLES** are available for applications below 2000 volts d-c, special skirted bushings for higher voltages.



**STANDARD CASE SIZES** are interchangeable, making it unnecessary to change drawings or circuit layouts.

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Cannon Plugs

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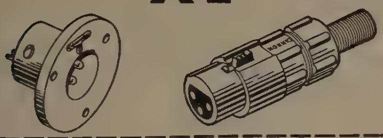
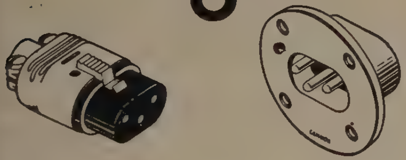
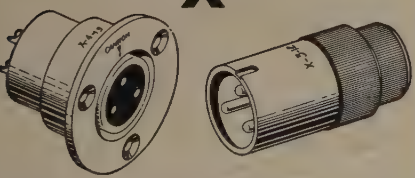


**P**

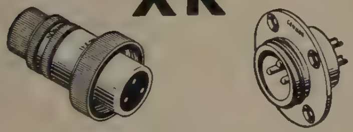
**O**



**X**



**XK**



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| 2 cps—150 kc | Frequency Range |
| 3% 5 cps—100 kc<br>5% 2 cps—5 cps<br>100 kc—150 kc | Accuracy |
| 2 meg. shunted by 15 μμf* | Input Impedance |

### AUDIO TO 2 MC Model 310A

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|---|---|
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| 10 cps—2 mc | Frequency Range |
| 3% to 1 mc<br>5% 1 mc—2 mc | Accuracy |
| 2 meg. shunted by 15 μμf* | Input Impedance |

### AUDIO TO 6 MC Model 314

| | |
|---|---|
| 1 mv—1000 v<br>(100 uv—1 mv without probe) | Voltage Range |
| 15 cps—6 mc | Frequency Range |
| 3% to 3 mc<br>5% 3 mc—6 mc | Accuracy |
| 11 meg. shunted by 7.5 μμf<br>(1 meg. shunted by 25 μμf without probe) | Input Impedance |

### PEAK-TO-PEAK Model 305

| | |
|---|---|
| 1 mv—1000 v pk-to-pk | Voltage Range |
| 10 cps—100 kc (Sine Wave) | Frequency Range |
| 3 μsec—250 μsec | Pulse Width |
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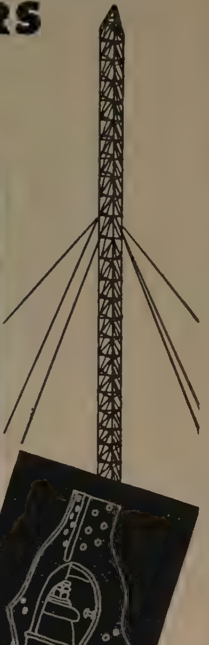
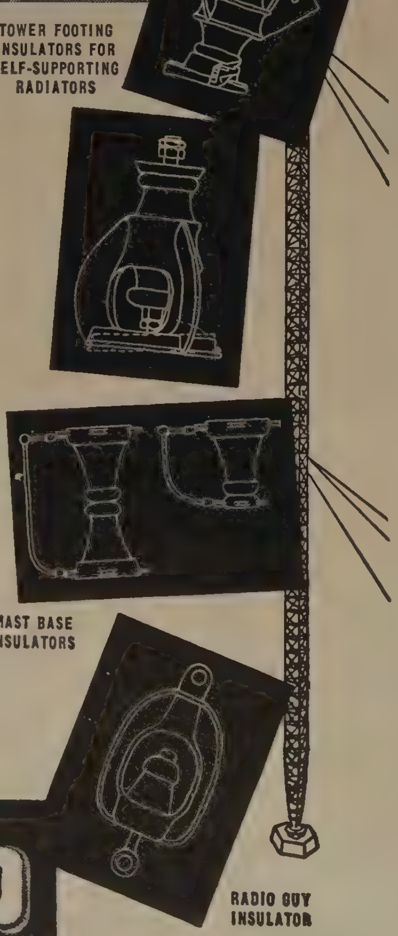
## ANTENNA TOWER INSULATORS

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For complete specifications on this and other Bruel & Kjaer instruments, write Brush Electronics Company, Dept. F 12A, 3405 Perkins Avenue, Cleveland 14, Ohio.

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| BL-1502 | Deviation Test Bridge |
| BL-1604 | Integration Network for Vibration Pickup, BL-4304 |
| BL-4304 | Vibration Pickup |
| BL-2002 | Heterodyne Voltmeter |
| BL-2105 | Frequency Analyzer |
| BL-2109 | Audio Frequency Spectrometer |
| BL-2304 | Level Recorder |
| BL-2423 | Megohmmeter and D. C. Voltmeter |
| BL-3423 | Megohmmeter High Tension Accessory |
| BL-4002 | Standing Wave Apparatus |
| BL-4111 | Condenser Microphone |
| BL-4120 | Microphone Calibration Apparatus and Accessory |
| BL-4708 | Automatic Frequency Response Tracer |

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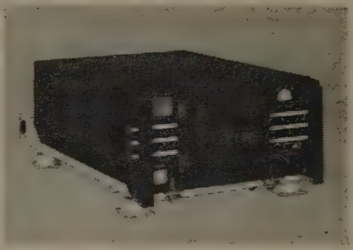

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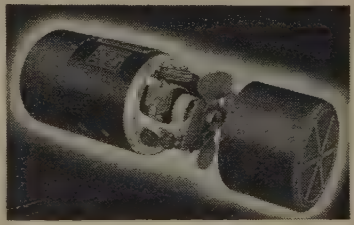

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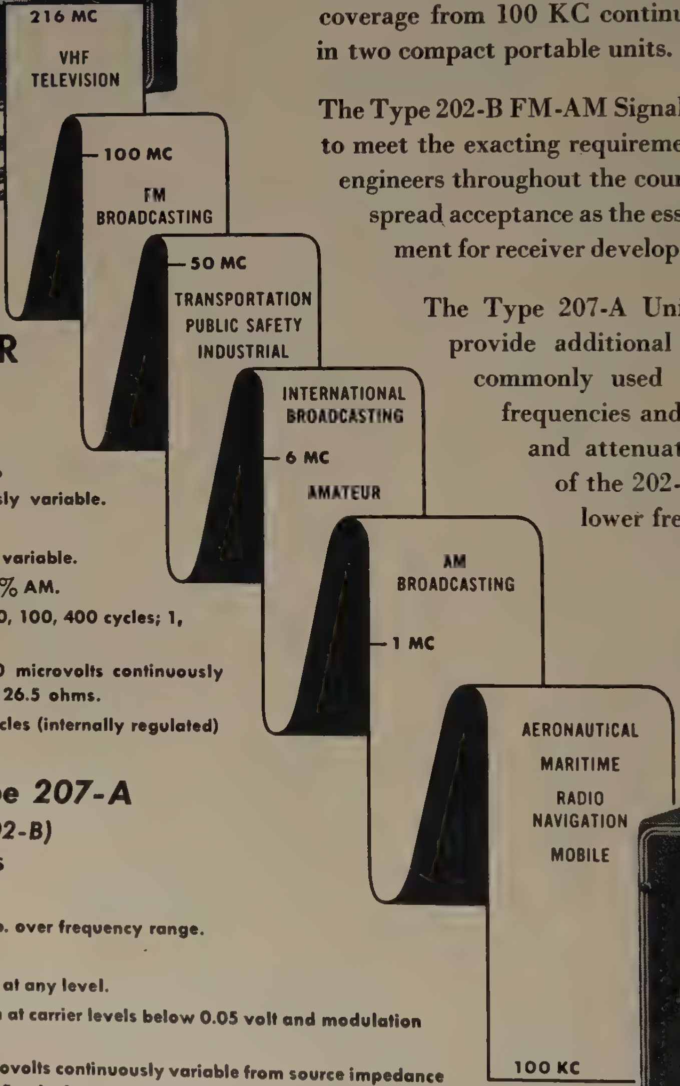

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### FM-AM SIGNAL GENERATOR

### Type 202-B

**SPECIFICATIONS**

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- **FM MODULATION:** 0—240 KC continuously variable.
- **FM DISTORTION:** Less than 2% at 75 KC.
- **AM MODULATION:** 0—50% continuously variable.
- **AM DISTORTION:** Approximately 5% at 50% AM.
- **INTERNAL MODULATING FREQUENCIES:** 50, 100, 400 cycles; 1, 5, 7.5, 10, 15 KC.
- **R. F. OUTPUT VOLTAGE:** 0.1 to 200,000 microvolts continuously variable from source impedance of 26.5 ohms.
- **POWER SUPPLY:** 105—125 volts, 50/60 cycles (internally regulated)

### UNIVERTER Type 207-A

(When used with 202-B)

**SPECIFICATIONS**

- **FREQUENCY RANGE:** 100 KC—55 MC.
- **FREQUENCY RESPONSE:** Flat within ±1 db. over frequency range.
- **FM-AM MODULATION:** See 202-B.
- **FM DISTORTION:** No appreciable distortion at any level.
- **AM DISTORTION:** No appreciable distortion at carrier levels below 0.05 volt and modulation of 50%.
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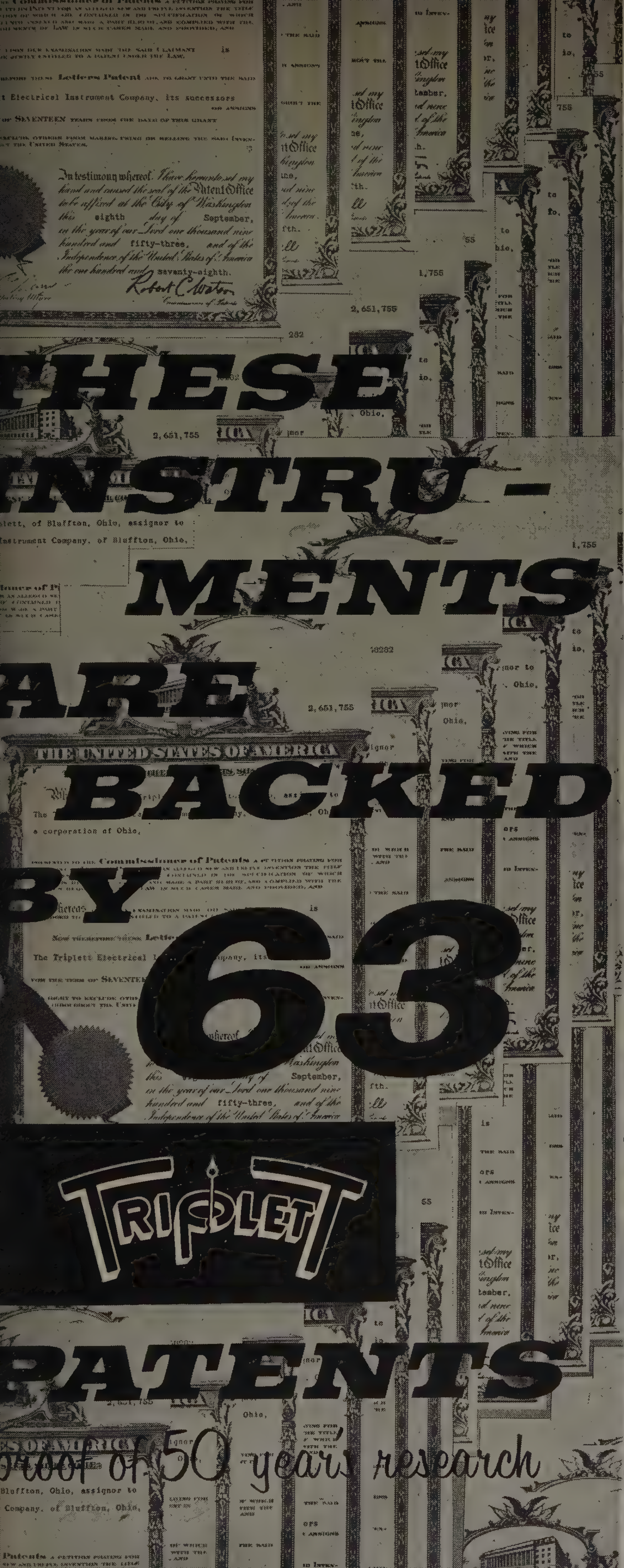

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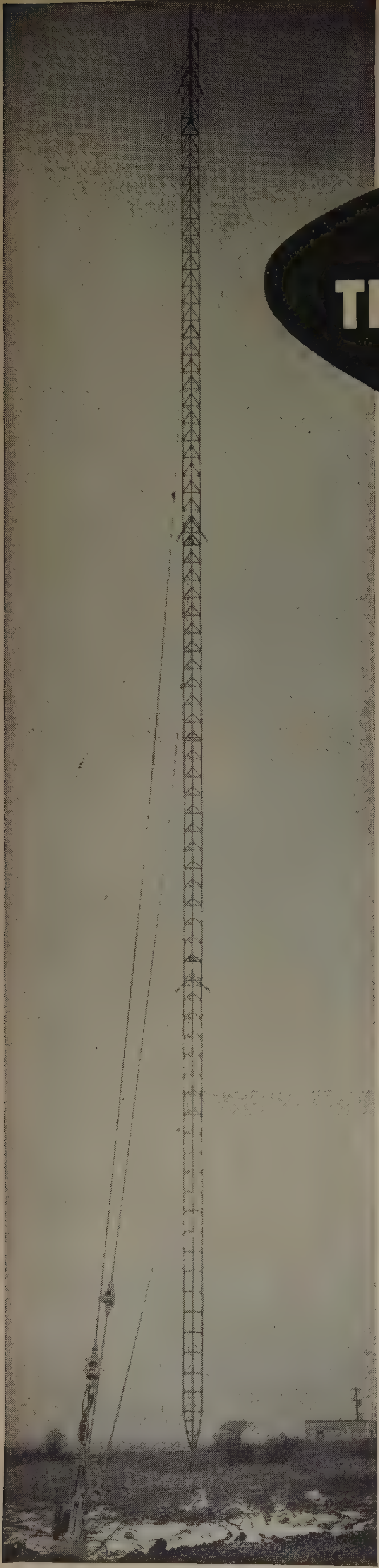

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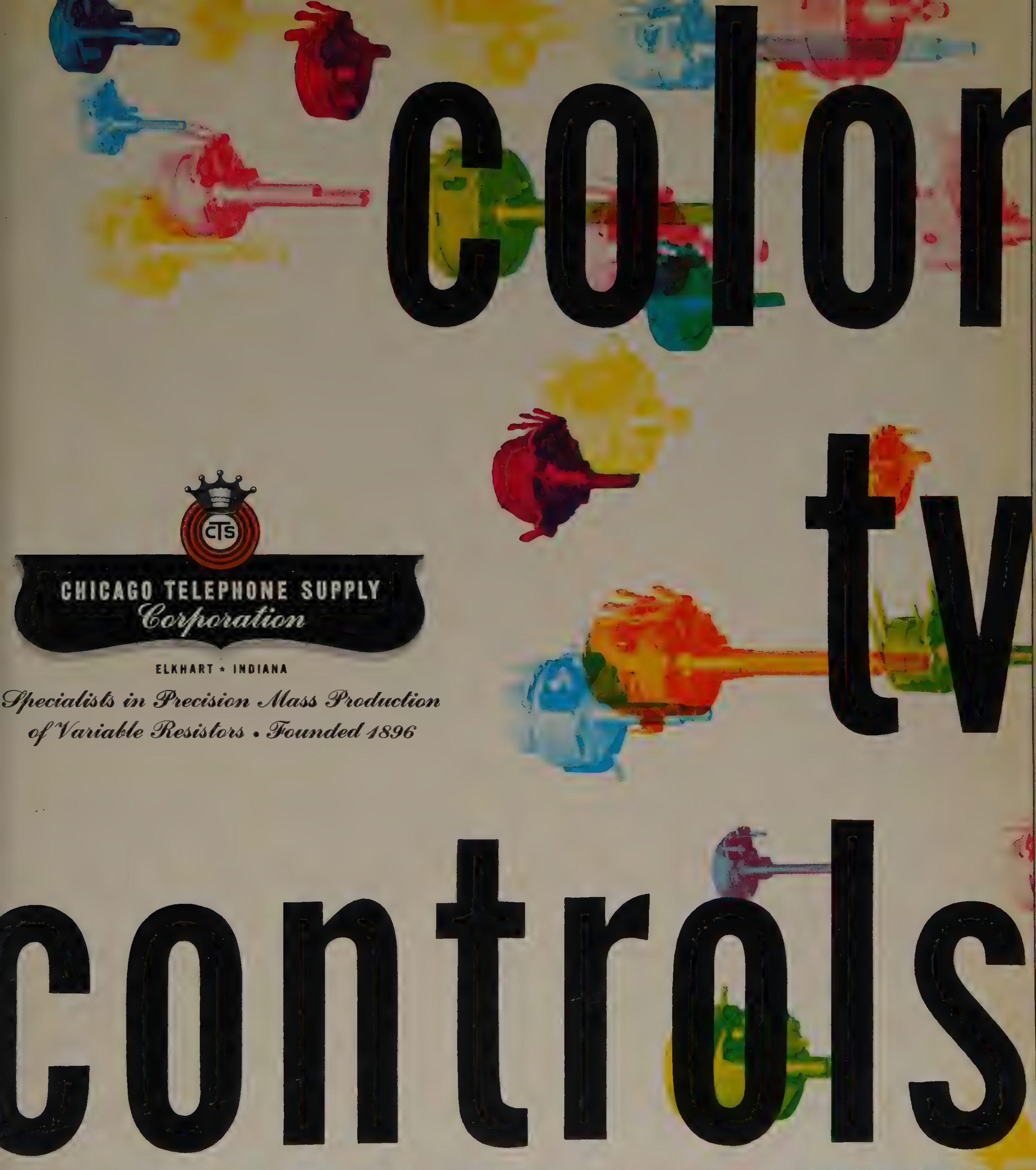

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Miniature 3/4
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comparable to large
bushing mounted con
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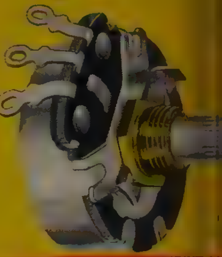
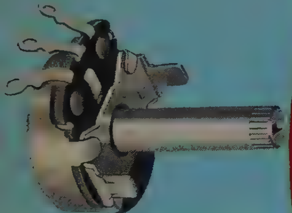


Concentric shaft tandem control with conventional bushing mounting. Designed for front panel dual knob applications, such as contrast and volume. Available in various combinations of composition or wirewound front and rear sections with or without on-off switch attached to rear section. CTS type GC-C252-45 with wirewound front section, composition rear section and on-off switch illustrated.

Ear mounted composition control. Simply twist two ears for rigid mounting. Eliminates bushing and mounting hardware. Available with shafts for knob operation or for preset applications with insulated or metal shaft. CTS type P45 with metal shaft illustrated.



Ear mounted two watt wi
wound available with or wit
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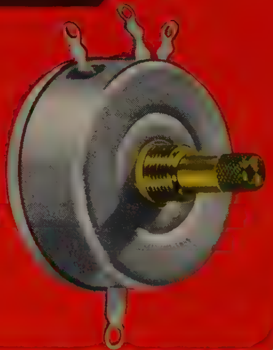
P-254 with tap illustrated.

Four watt wirewound control available with or without center tap. CTS type 27 with tap illustrated.



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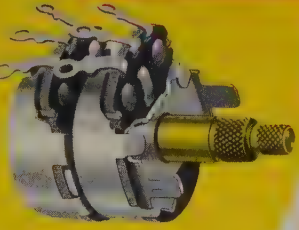
Ear mounted tandem for preset applications. Combines panel space saving features of a concentric tandem with the economy of an ear mounted unit. Available in various combinations of composition or wirewound front and rear sections. CTS type P-C2-45 with composition front and rear sections illustrated.



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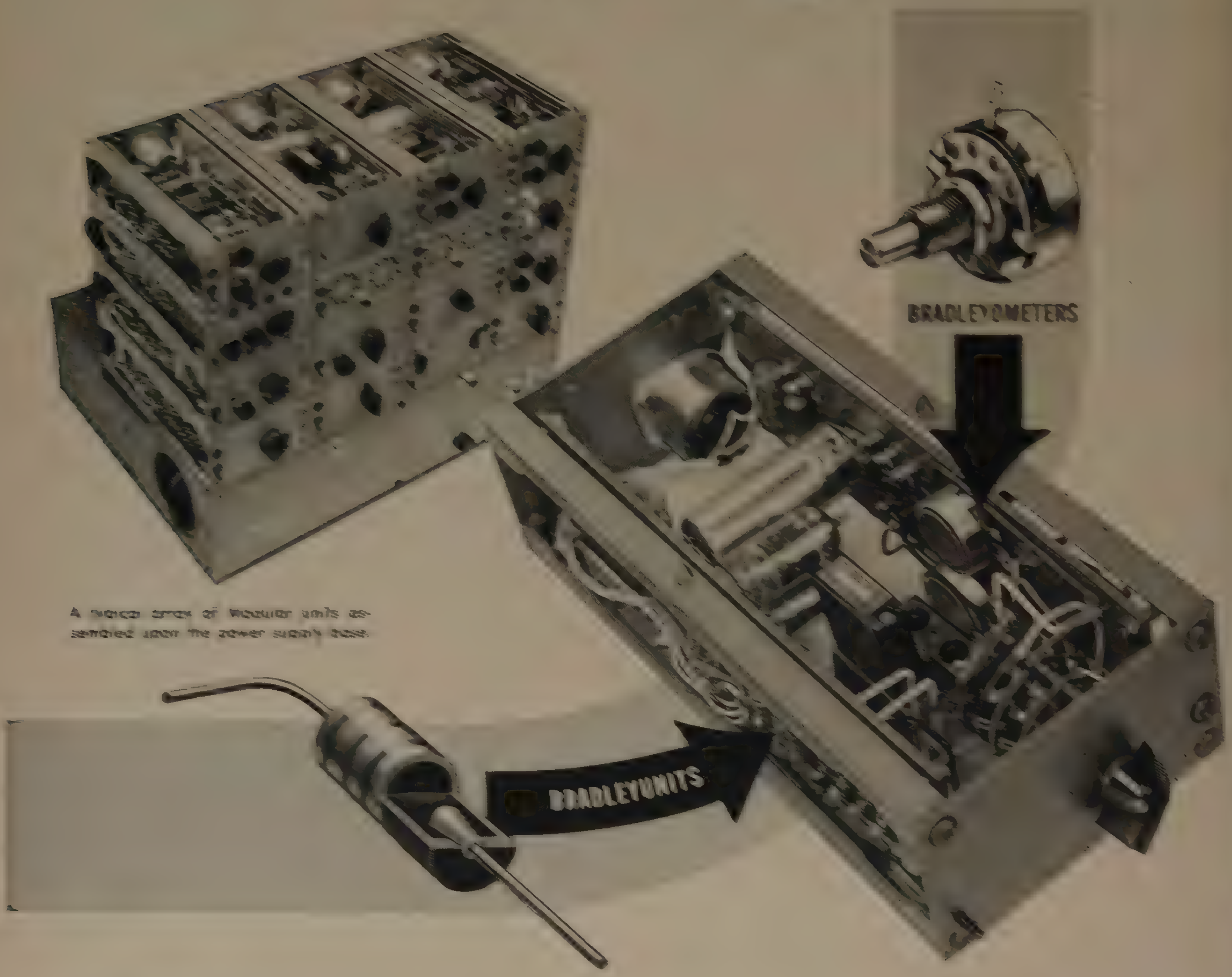
# AUDIO PRODUCTS MODULAR SYSTEM

*equipped with* **AB** *Quality Resistors*



A typical array of Modular units assembled upon the power supply base.

The Modular system, developed by Audio Products Corporation of Los Angeles, consists of 16 Modular units of various electronic functions which may be interconnected to perform most basic pulse operations. With this system of compatible units, research engineers can think and work in "block diagram" terms, and thus be freed of many circuit details.

Bradleyunit fixed resistors and Bradleyometer adjustable resistors are used in the various Modulars to assure stability of performance.

Bradleyunits are ultra-conservatively rated at 70C ambient temperature—not the usual 40C. Their resistance values exhibit no erratic changes . . . nor do they open circuit.

Bradleyometers have solid molded resistor elements that are not affected by temperature or humidity, and improve with use.

Get the data on these QUALITY products by sending for Allen-Bradley electronic fixed and adjustable resistor bulletins, today.

---

Allen-Bradley Co., 114 W. Greenfield Ave., Milwaukee 4, Wis. • In Canada—Allen-Bradley Canada Limited, Galt, Ont.

## ALLEN-BRADLEY

**FIXED AND ADJUSTABLE RADIO RESISTORS**

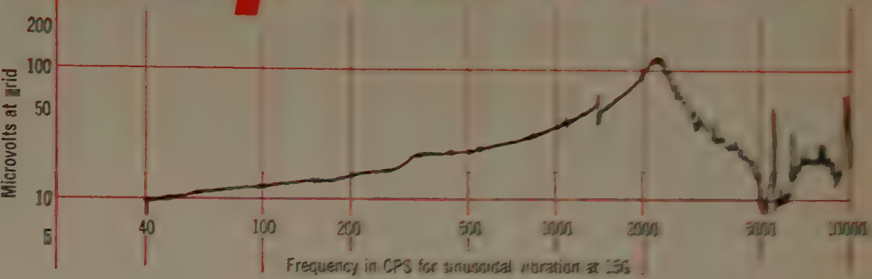
QUALITY

# low microphonics?

## THIS IS IT!

RAYTHEON

**CK6533**
**a new guided missile**
**RELIABLE**
**SUBMINIATURE**
**TRIODE**



**Pictured is the vibration output voltage of a typical CK6533 tube over a wide frequency range, in terms of microvolts at the grid when the tube is vibrated at 15G and operated at Ep = 120V, Rk = 1500 ohms.**

**The CK6533 is designed and manufactured to meet the latest military specifications for guided missile application.**

Mutual conductance is 1750 umhos.
Amplification factor is 53.
Plate current is 0.9 ma.

# superior stability?

## for DC AMPLIFIER and COMPUTER service

RAYTHEON

**CK5755**

**RELIABLE**
**TWIN TRIODE**

## THIS IS IT!

electrical **stability**
mechanical **stability**
**low microphonic** output
**low grid current**
fine **balance** between sections

These characteristics are *designed into* the CK5755, making it the ideal tube for precision DC amplifiers, computers, highly stable regulated power supplies and many other critical applications.

| | | |
|---|---|---|
| Grid current | | $10^{-8}$ amp. maximum |
| Plate current balance (Elc-E2c) | (typically 0.05V) | 0.3V maximum |
| Plate current drift (Ec after 5 min.) | | 2.0mV maximum |
| Plate current drift (Ec after 16 hours) | | 5.0mV maximum |
| Mechanical stability (Ec after 400-600G shock) | | 25.0mV maximum |

RAYTHEON
*Excellence in Electronics*

**RAYTHEON MANUFACTURING COMPANY**

Receiving Tube Division — Home Office: 55 Chapel St., Newton 58, Mass. Bigelow 4-7500
For application information write or call the Home Office or: 4935 West Fullerton Avenue, Chicago 39, Illinois, NAtional 2-2770
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RAYTHEON MAKES ALL THESE:

RELIABLE SUBMINIATURE AND MINIATURE TUBES • SEMICONDUCTOR DIODES AND TRANSISTORS • NUCLEONIC TUBES • MICROWAVE TUBES • RECEIVING AND PICTURE TUBES

90662
46721
90661
46702-3-4-5
90651
90661
GRID-DIP OSCILLATOR

# Designed for Application

## Grid Dip Meters

Millen Grid Dip Meters are available to meet all various laboratory and servicing requirements.

The 90662 Industrial Grid Dip Meter completely calibrated for laboratory use with a range from 225 kc. to 300 mc. incorporates features desired for both industrial and laboratory application, including three wire grounding type power cord and suitable carrying case.

The 90661 Industrial Grid Dip Meter is similar to the 90662 except for a reduced range of 1.7 to 300 mc. It likewise incorporates the three wire grounding type cord and metal carrying case.

The 90651 Standard Grid Dip Meter is a somewhat less expensive version of the grid dip meter. The calibration while adequate for general usage is not as complete as in the case of the industrial model. It is supplied without grounding lead and without carrying case. The range is 1.7 to 300 mc. Extra inductors available extends range to 220 kc.

The Millen Grid Dip Meter is a calibrated stable RF oscillator unit with a meter to read grid current. The frequency determining coil is plugged into the unit so that it may be used as a probe.

These instruments are complete with a built-in transformer type A.C. power supply and internal terminal board to provide connections for battery operation where it is desirable to use the unit on antenna measurements and other usages where A.C. power is not available. Compactness has been achieved without loss of performance or convenience of usage. The incorporation of the power supply, oscillator and probe into a single unit provides a convenient device for checking all types of circuits. The indicating instrument is a standard 2 inch General Electric instrument with an easy to read scale. The calibrated dial is a large 205° drum dial which provides seven direct reading scales, plus an additional universal scale, all with the same length and readability. Each range has its individual plug-in probe completely enclosed in a contour fitting polystyrene case for assurance of permanence of calibration as well as to prevent any possibility of mechanical damage or of unintentional contact with the components of the circuit being tested.

*The Gride Dip Meters may be used as:*

1. A grid Dip Oscillator
2. An Oscillating Detector
3. A Signal Generator
4. An Indicating Absorption Wavemeter

The most common usage of the Grid Dip Meter is as an oscillating frequency meter to determine the resonant frequencies of de-energized tuned circuits.

Size of Grid Dip Meter only (less probe): 7 in. x $3\frac{3}{16}$ in. x $3\frac{3}{8}$ in.

JAMES MILLEN MFG. CO., INC.
MAIN OFFICE AND FACTORY
MALDEN, MASSACHUSETTS, U.S.A.

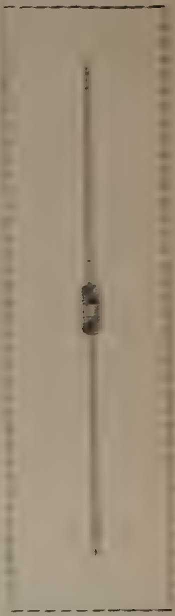
# Miniaturization with Hughes Diodes

## *New computer matrix has high component density*

*This experimental reading gate matrix for airborne computers effectively utilizes the subminiature size of Hughes Point-Contact Germanium Diodes*. Developed by the Miniaturization Group of Hughes Research and Development Laboratories, the unit measures 5¼ by 3½ by 1½ inches (including plugs and frame). It contains 504 diodes, 209 resistors. Average component density: 94.5 per cubic inch.*

Frequently, space requirements of conventional wiring techniques will not permit electronic equipments to be miniaturized to the same extent as the components. However, spot-welded connections can effectively reduce wiring space . . . and it is easy to spot-weld the dumet leads of Hughes diodes. There is no adverse effect on diode characteristics, even when the connections are welded close to the diode body. With Hughes diodes, designers can take full advantage of advanced packaging and wiring techniques.

Hughes diodes are easy to mount in conventional assemblies or in subminiature equipment. In service, these diodes have earned a reputation for reliable performance and stability under severe operating conditions. Make your selection from the many standard and special types available — all listed and described in our new Bulletin 10-1a.



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Reprints of a paper describing the packaging techniques of the subminiature matrix are available, too. Your copy will be sent promptly on request.

**Hughes**

SEMICONDUCTOR SALES DEPARTMENT

*Aircraft Company, Culver City, Calif.*

New York   Chicago

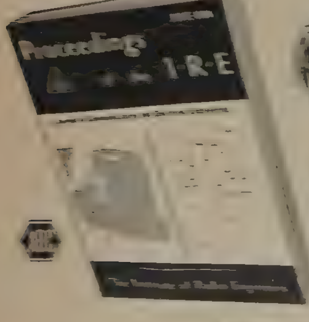
# How much are radio-electronic engineers worth to you per thousand?

Whether you buy an engineering audience on the basis of cost-per-thousand or on the basis of quality . . . remember this. Either way, your advertising dollar buys greatest value in "Proceedings of the I·R·E."

The Institute of Radio Engineers for over 31 years has held to the conviction that its advertising rates would do most to benefit the industry and help it grow *by being economical*. As a professional society, the Institute has enjoyed financial advantages which have been passed along to advertisers in the form of low cost advertising to a high quality audience. That's why the page rate per thousand engineer-readers of "Proceedings of the I·R·E" is the lowest in the radio-electronic industry by a considerable margin.

In today's highly competitive market, this gives you a definite advantage. Simply compare the rates for "Proceedings of the I·R·E" with any publications you choose. Check the high quality of its editorial content. Take a careful look at its audience—41,625 (ABC) engineers at the top technical level. Then add it all up and you'll see for yourself why "Proceedings of the I·R·E" is the magazine of influence in the fast-growing radio-electronic industry.

## Engineers are educated to specify and buy!



**"Proceedings of the I·R·E"**

Published by
THE INSTITUTE OF RADIO ENGINEERS
Advertising Department
1475 Broadway, New York 36, N.Y. BRyant 9-7550

CHICAGO • BEREA, OHIO • LOS ANGELES • SAN FRANCISCO

The magic evolution of radiation—controlled by the radio tube—has entered its third great epoch.

## EARS!

*First came the audio stage, expressed in radio: signal, human voice and glorious fidelity in music*

## EYES!

*Second: video in television, even now changing to soul satisfying color.*

## BRAINS!

*And now comes the era of the electronic computer—the signal that is detected, stored (remembered, if you wish) totalled and graphed; solving problems too staggering and monotonous for the human mind.*

The electronic computer's base component is the radio tube. Its design and production is the brilliant product of the radio engineer. Advances in the computer, which soon will be as commonly used as the typewriter and adding machine, have been aided by "history making issues" of "Proceedings of the I·R·E".

The era of the electronic computer opens a vast new manufacturing market. The surest and most economical way to sell to it is by reaching the minds of men who design and make computers—radio and electronic engineers. "Proceedings of the I·R·E" puts your selling message monthly before the "thinking and doing" engineers in the fabulous, fast-moving radio-electronic industry. Circulation 41,625 (ABC).

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**700 EXHIBITS**
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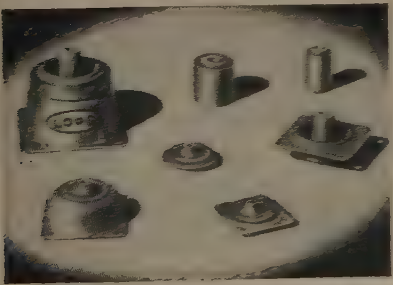
ADVERTISEMENT

## Lord Vibration Control Mountings . . . The Most Effective Protection For Electronic Equipment

In the rapidly advancing field of electronics, the control of destructive vibration and isolation of damaging shock are prime factors in the consideration of design engineers. Lord, Headquarters for Vibration Control, is constantly working with electronics engineers to improve the methods for protecting sensitive mechanisms.

For instance, Varo Static Converters which change alternating to direct current for aircraft with less than 1% voltage ripple are protected against shock and vibration by Lord Mountings. High fidelity Audio frequency electronic equipment such as Collins Radio Company manufactures is protected from vibration and shock through the use of Lord Mountings. The 212A-1 Broadcast Station Speech Input Console by Collins requires 28 Lord square Plate Form Mountings to protect each amplifier stage individually. This prevents mechanical interaction between stages and lessens acoustical feed-back effects.

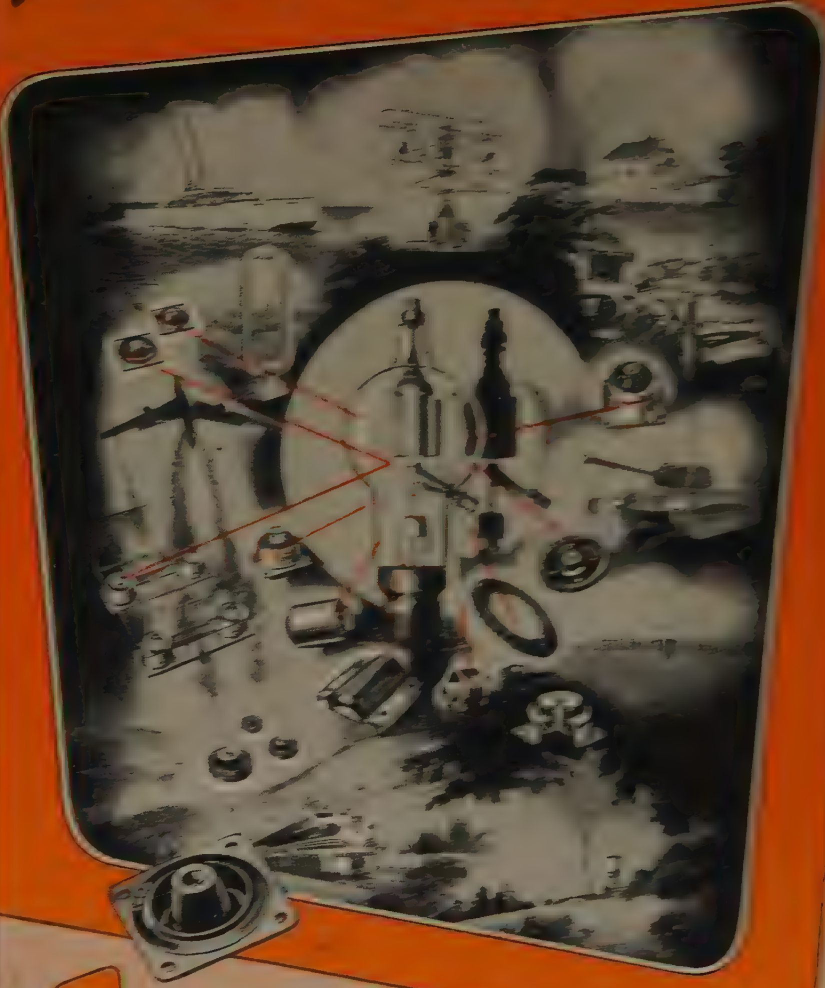


Again the Agnew Spark Plug Welder by Agnew Electric Company uses Lord Mountings to support the electronic weld timers to prolong the useful service life of Mercury Vapor Tubes.

Lord Mountings, which you see illustrated in the accompanying advertisement, are used in a wide diversity of applications to protect electronic equipment and sensitive instruments. Business machines and such sensitive mechanisms, the accuracy of which must be perfect, are improved in operation and protected from damaging vibration and shock by Lord Mountings.

The Lord Manufacturing Company, Erie, Pa., offers a vast reservoir of recorded experience in the solution of vibration and shock problems. Your request for help on your own problem is welcomed.

# LORD MOUNTINGS PROTECT INSTRUMENTS *and* ELECTRONIC EQUIPMENT *from* VIBRATION *and* SHOCK DAMAGE • • •



VIBRATION and shock are natural enemies of electronic equipment and precision instruments . . . To control the damage which these enemies can do, Lord Vibration Control Mountings and Bonded Rubber Parts are used to very profitable advantage. More than a quarter century's experience in dealing with vibration and shock is yours when you take advantage of Lord engineering assistance. The result of such consultation is full protection for electronic units and sensitive instruments by correctly designed and precisely manufactured Lord Mountings and Bonded-Rubber parts.

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LORD

*Headquarters for*
VIBRATION CONTROL

# COLOR TV COMES OF AGE

**The RCA 21-INCH COLOR PICTURE TUBE,** *the tube in your future,* is here! Intensive RCA research brings you full-sized pictures of excellent clarity, and brightness . . . makes production-line colo TV a reality. Outstanding features of the new RCA-21AXP22 are:

21″ round tube with aluminized phosphor dot screen gives largest picture in color TV, a full 250 squar inches of brilliant color.

Metal shell means lighte weight and greater mechanical strength.

Thermally-compensated, spherical shadow mask permits uniform expansion of mask fo improved color registration and brighte pictures.

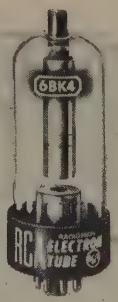
70° deflection angle— combined with a short electron gun having improved resolution— provides a short tube which permits reduced cabinet depth.

**RCA-21AXP22**
- **21-inch metal envelope**
- **electrostatic focus**
- **magnetic deflection**
- **magnetic convergence**

**Three New RCA-Developed Receiving Tubes for Color TV**

6BL4
RCA ELECTRON TUBE

**RCA-6BL4—** Half-Wave Rectifier Tube (Damper Diode)



**RCA-6BK4—** Sharp-Cutoff Beam Triode (Shunt Voltage Regulator)

6CB5
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**RCA-6CB5—** Beam PowerTube (Horizontal-Deflection Amplifier)

*RCA pioneered and developed compatible color television*

RCA®

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The first audio frequency filter to combine the advantages of passive network and continuously variable control. The continuously variable control feature on the Allison low-pass, high-pass and band-pass filter is made possible by incorporating a tested and proven variable inductor. This facilitates filter tuning at audio frequencies as simply and easily as a variable condenser tunes radio frequencies.

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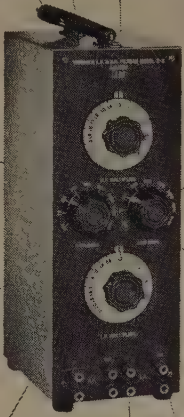

*Model 2-B Filter*

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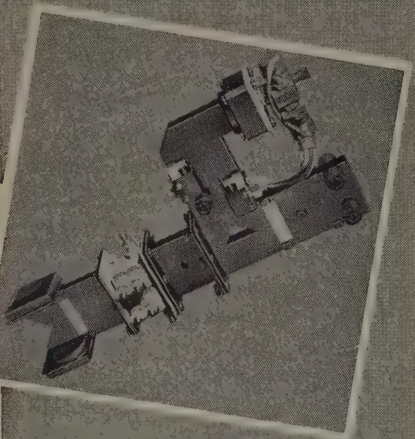

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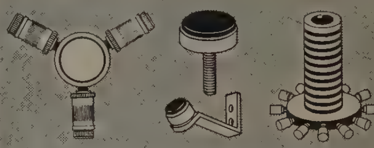

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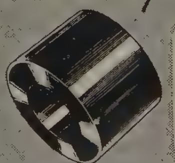

Oil-free, self-lubricating Bushings and Bearings (applicable —100° to +300° F.; with expansion coefficient half that of steel will not seize shaft at low temperature); oil-free Piston Rings, Seal Rings, Thrust and Friction Washers, Pump Vanes.

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BECKMAN

*SHASTA Model*

**201 ELECTRONIC VOLTMETER**

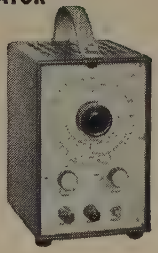
1.5 to 1,500 volts d.c.; 4 to 4,000 volts a.c. peak to peak, 1.5 to 1,500 r.m.s. Resistance range 0 to 1,000 megohms. Price, $68.00*

Developed by a division of Beckman Instruments Inc., manufacturer of quality precision instrumentation for more than 20 years, the new SHASTA line of integrated electronic test instruments is designed from the user point of view to offer new, higher standards of performance, reliability and overall value. Here are typical examples:

*SHASTA Model*

**301 AUDIO OSCILLATOR**

Range, 12 cycles to 1.1 m.c. Output level ± 1 db over entire range. Power output 150 milliwatts; distortion less than 5%. Price, $95.00*



*SHASTA Model*

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Range 1.0 to 100 megohms, lowest measurable, 100 K. Accuracy, 0.25%. Price $150*

*Prices f.o.b. factory

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Before you specify or buy test instrumentation, investigate the outstanding features and values of the Shasta line. Write *now* for technical bulletin and price lists; please request bulletin SA 12.

# *From servo-mechanisms to electronic-computers,* "RADIO" is a way of THINKING!

**Far-reaching progress in the radio-electronic field is no "happy accident." Television, electronic computers and the "radiation" power of the atom, which soon will be harnessed to industry were not discovered . . . they were engineered.**

**From "fission" to "computation," these engineering achievements are accomplished through an enormous process of information exchange—the methodical and brilliant teaming together of engineering *thinking* to solve a problem. In radio this work has been done deliberately by a growing engineering society, through its meetings and published proceedings, which unleash the creative minds of men. In 1953, "Proceedings of the I-R-E" published 1818 text pages, exclusive of product news and departmental features. This is the word-count equivalent of seven 500-page textbooks on radio-electronics for engineers. It exceeds the contents of the next two contemporary publications put together. This "high" in genuine reader service was logically matched by advertising worth over a half-million dollars, by firms investing in the engineers' reading interest and benefiting by it.**

Plan now to see
**700 EXHIBITS**
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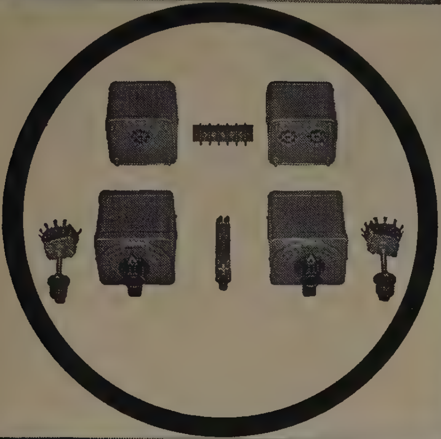
SIMPLIFY
CUSTOM
INSTALLATION

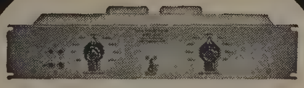


The 4200 Sound Effects Filter and 4201 Program Equalizer are now available in component form, as illustrated, for the custom builder.

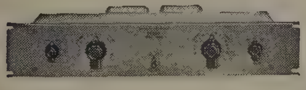
In addition to the flexibility of installation, all the features and characteristics of the standard models are retained.

The high and low sections of either model may be obtained separately. Complete wiring instructions included.

*Send for Bulletin* TB-4



Model 4200 Sound Effects Filter
*(Send for Bulletin* S*)*



Model 4201, Program Equalizer
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A COMPLETE
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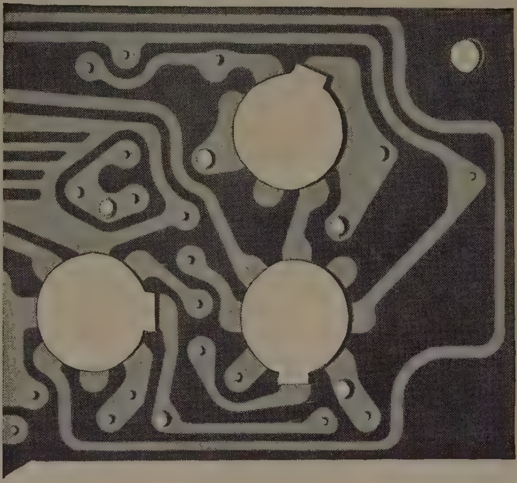
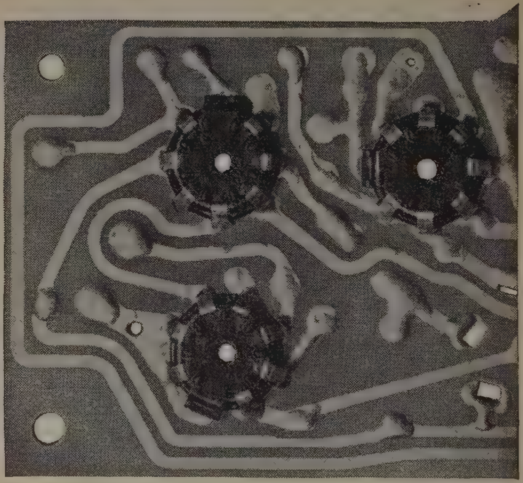
SERVICE



Printed Circuit Boards Printed and Accurately Punched Ready for Components.



Plus the Additional Service of Complete or Partial Assembly to Customers' Specifications.

**P. S.** *Don't forget Eby Printed Circuit Sockets.*

FOR THE BEST IN PRINTED CIRCUITS
. . . FACILITIES AND SERVICE, IT'S

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Leading a brand new line...

1000°

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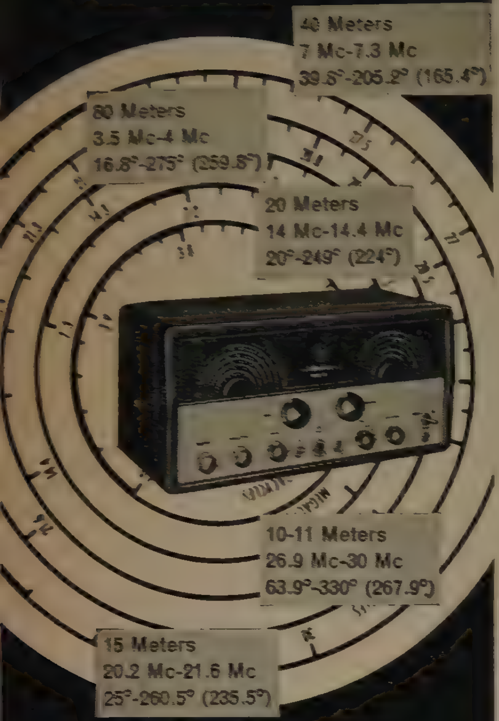

**MODEL S85**
S-85 Receiver (AC)
S-86 Receiver (AC-DC)
105/125 V. 50/60 cycle
Either $119.95

We here at Hallicrafters are proud of our new communications line, especially the new S-85 receiver with over 1000° of calibrated bandspread. Broadcast band 540-1680 Kc and three short-wave bands 1680 Kc—34 Mc on large easy to read dial. Separate bandspread tuning condenser and built-in speaker. Seven tubes plus rectifier. Coupon below brings complete specifications.

*Used by 33 governments,*
*Sold in 89 countries.*

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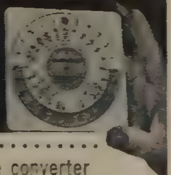

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NOW USED BY THE NATION'S LARGEST PRODUCER OF AN CONNECTORS

Simplicity of operation . . . uniform, high quality performance . . . characteristics that cannot be achieved with any other gold plating process—just a few of the reasons why American Phenolic Corp. uses the SEL-REX BRIGHT GOLD PROCESS to electroplate high quality AMPHENOL AN Connector contacts.

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Dept. IRE-12, 229 Main Street • Belleville 9, N.J.

***Here are the advantages of plating with the Sel-Rex BRIGHT GOLD PROCESS:***

**LONGER LIFE**—extremely hard deposit is twice that of conventional gold, thus resists wear and abrasion even on sliding or wiping contacts.

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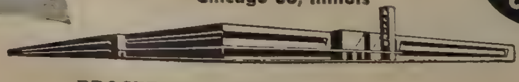


# MICROWAVE SIGNAL GENERATORS

Complete coverage of
the range 950-10,800 mcs/sec.

with Polarad single dial operation

Four new Microwave Signal Generators covering the range 950-10,800 mcs/sec. All with famous **Polarad single dial operation**. Each provides the maximum working range possible in one compact signal generator. And, additional Polarad Signal Generators are available to cover 12.8 to 39.7 kmc.

These features on all MSG units assure fast and simple operation: direct reading, single dial frequency control that tracks reflector voltages automatically . . . direct reading attenuator dial . . . conveniently placed controls, in logical sequence . . . high visibility on the face of each instrument.

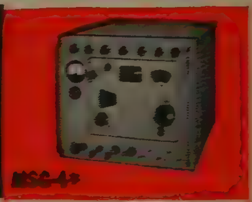
Polarad Signal Generators are built to the same high standards required for military equipment. They are practical for the factory assembly line—engineered ventilation assures continuous and stable operation of all instrument functions. Components are readily accessible for easy maintenance. And laboratory accuracy is guaranteed under the most rigorous operating conditions.

Write directly to Polarad or your nearest Polarad representative for details.

MSG-1

MSG-2

MSG-3


MSG-4*

| | MSG-1 | MSG-2 | MSG-3 | MSG-4* |
|---|---|---|---|---|
| Frequency Range | 950-2400<br>MCS/sec. | 2150-4600<br>MCS/sec. | 4450-8000<br>MCS/sec. | 6950-10,800<br>MCS/sec. |
| | (Frequency set by means of a single directly calibrated control) | | | |
| Frequency Accuracy | ±1% | ±1% | ±1% | ±1% |
| Power Output | 1 MW | 1 MW | .2 MW | .1 MW |
| Attenuator Range | 120 db | 120 db | 120 db | 120 db |
| Attenuator Accuracy | ±2 db | ±2 db | ±2 db | ±2 db |
| Output Impedance | 50 ohms | 50 ohms | 50 ohms | 50 ohms |
| Input Power | 115V±10%<br>60 cps | 115V±10%<br>60 cps | 115V±10%<br>50-1000 cps | 115V±10%<br>50-1000 cps |
| Internal Pulse Modulation: | | | | |
| Pulse Width | 0.5 to 10 microseconds | | | |
| Delay | 3 to 300 microseconds | | | |
| Rate | 40 to 4000 pulses per second | | | |
| Synchronization | Internal or external, sine wave or pulse | | | |
| Internal FM: | | | | |
| Type | Linear sawtooth | | | |
| Rate | 40 to 4000 cps | | | |
| Synchronization | Internal or external, sine wave or pulse | | | |
| Frequency Deviation | ±2.5 MCS | ±2.5 MCS | ±6 MCS | ±6 MCS |
| External Pulse Modulation: | | | | |
| Polarity | Positive or Negative | | | |
| Rate | 40 to 4000 pulses per second | | | |
| Pulse width | 0.5 to 2500 microseconds | | | |
| Pulse separation | (For multiple pulses) 1 to 2500 microseconds | | | |
| Output Synchronizing Pulses: | | | | |
| Polarity | Positive, delayed & undelayed | | | |
| Rate | 40 to 4000 pps | | | |
| Voltage | Greater than 25 volts | | | |
| Rise time | Less than 1 microsecond | | | |
| Size \| Approx. weight | 17" long x 13¼" high x 15½" deep \| 60 lbs. | | 17" long x 15" high x 19½" deep \| 100 lbs. | |

*Also available—MSG 4A 6,950—11,500 MCS/sec.

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Clamp in Cap.

S-306-AB
Socket with
Angle Brackets.

Jones Series 300 illustrated. Small Plugs & Sockets for 1001 Uses. Cap or panel mounting.

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- Metal Caps, with formed fibre linings.
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SUBSIDIARY OF UNITED-CARR FASTENER CORP.

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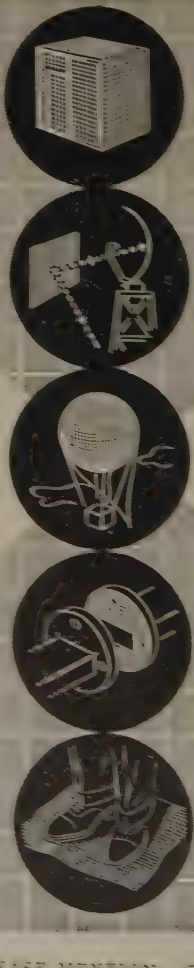

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An ATR SHAV-PAK will solve this predicament!
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$9.95 LIST PRICE

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| 6-SPB | 6 | 115 volts | 15 | 9.95 |
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WITH GREATER OUTPUT

DICTATE REPORTS ACCURATELY-PROMPTLY!

make your car, boat or plane a "rolling office" with ATR INVERTERS for changing your storage battery current to A. C. *Household* ELECTRICITY *Anywhere* in your own car!

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ATR INVERTERS . . .
especially designed for operating standard 110 volt A. C.

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- TAPE RECORDER
- WIRE RECORDERS

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|---|---|---|---|---|
| 6-DME | 6 | 115 volts | 30-40 | 19.95 |
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Above Inverters also available for 12-volt operation.

*See your jobber or write factory today for complete information*

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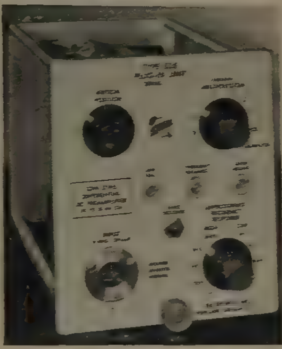
# NEW! Two more PLUG-IN UNITS for Tektronix *Type* 531 *and* 535 Oscilloscopes

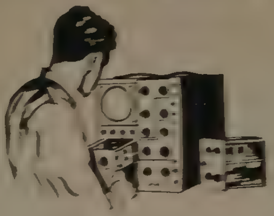


**Type 53E Low-Level Differential Preamplifier**

50 microvolt/cm to 10 millivolt/cm calibrated sensitivity. Frequency response, 0.06 cycles to 60 kc. Rejection ratio, 80,000 to 1 for in-phase signals at full gain. 7μv rms maximum combined noise and hum with input grids grounded at the input connector . . . . . . . . . . . . . $165

**Type 53G Differential Wide-Band DC Preamplifier**

DC to 10 mc, risetime 0.035 μsec. 0.05 v/cm to 20 v/cm calibrated sensitivity. Separate step attenuators for both inputs. Better than 100-to-1 common-mode rejection at full gain for the entire passband . . . . . . . . . . . $175



A new micro-sensitive preamplifier, Type 53E . . . and a new wide-band differential preamplifier, Type 53G . . . greatly expand the working range of Type 531 and Type 535 Oscilloscopes. Application areas entered with these new plug-in units ordinarily require the acquisition of cumbersome auxiliary equipment or separate specialized oscilloscopes. But you can equip your Type 531 or Type 535 for either or both types of work for just the cost of the plug-in unit . . . without loss of performance in its other applications. *Your Type 531 or Type 535 becomes potentially more useful to you each time Tektronix announces a new plug-in unit.*

## OTHER PLUG-IN UNITS

**Type 53A** — DC to 10 mc, 0.035 μsec risetime; 0.05 v/cm to 50 v/cm, calibrated . . . . . . . . . . . . . . . . . . . . . . $85

**Type 53B** — Same as Type 53A with additional calibrated ac-sensitivity to 5 mv/cm . . . . . . . . . . . . . . . . . . . . . . $125

**Type 53C** — Dual-trace unit. Two identical amplifier channels, dc to 8.5 mc, 0.05 v/cm to 50 v/cm. Electronic switching triggered by oscilloscope sweep . . . or free running at about 100 kc . . . . . . . . . . . . . . . . . . . . . . $275

**Type 53D** — Differential input, high gain. DC to 350 kc at 1 mv/cm — passband increasing to 2 mc at 50 mv/cm. Full range — 1 mv/cm to 125 v/cm . . . . . . . . . . . . . . . . . . . . . . $145

## OSCILLOSCOPE CHARACTERISTICS

***Advanced Cathode-Ray Tube***
Entirely new metallized crt provides full 6cm x 10cm undistorted viewing area . . . 50% more vertical deflection than previous high-sensitivity tubes. 10 kv accelerating potential permits single-sweep photography at the fastest sweep speed.

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0.02 μsec/cm to 12 sec/cm, continuously variable. 24 calibrated sweeps from 0.1 μsec/cm to 5 sec/cm, accurate within 3%. Accurate 5-x magnification.

***Wide-band Output Amplifier***
DC-coupled amplifier designed for use with all Type 53-series Plug-in Units.

***Balanced Delay Network***
0.25 μsec signal delay in vertical amplifier.

***Sensitive Horizontal Amplifier***
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Internal or external, with amplitude level selection or automatic triggering.

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0.2 mv to 100 v in 18 steps, accurate within 3%.

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***CRT Beam Position Indicators***

***Electronic Voltage Regulation***

*Write for A-[illegible], free 12-page specification booklet*

TYPE 535

**Type 531** — $995 plus price of desired plug-in units.

**Type 535** — Same characteristics — plus delayed sweeps. 1 μsec to 0.1 sec calibrated delay in 12 ranges. Incremental accuracy within 0.2% of full scale. Conventional or triggered operation . . . . . . . $1300 plus price of desired plug-in units. Prices f.o.b. Portland (Beaverton), Oregon.

**Your Tektronix Field Engineer or Representative will gladly arrange a demonstration at your convenience . . . call him today.**

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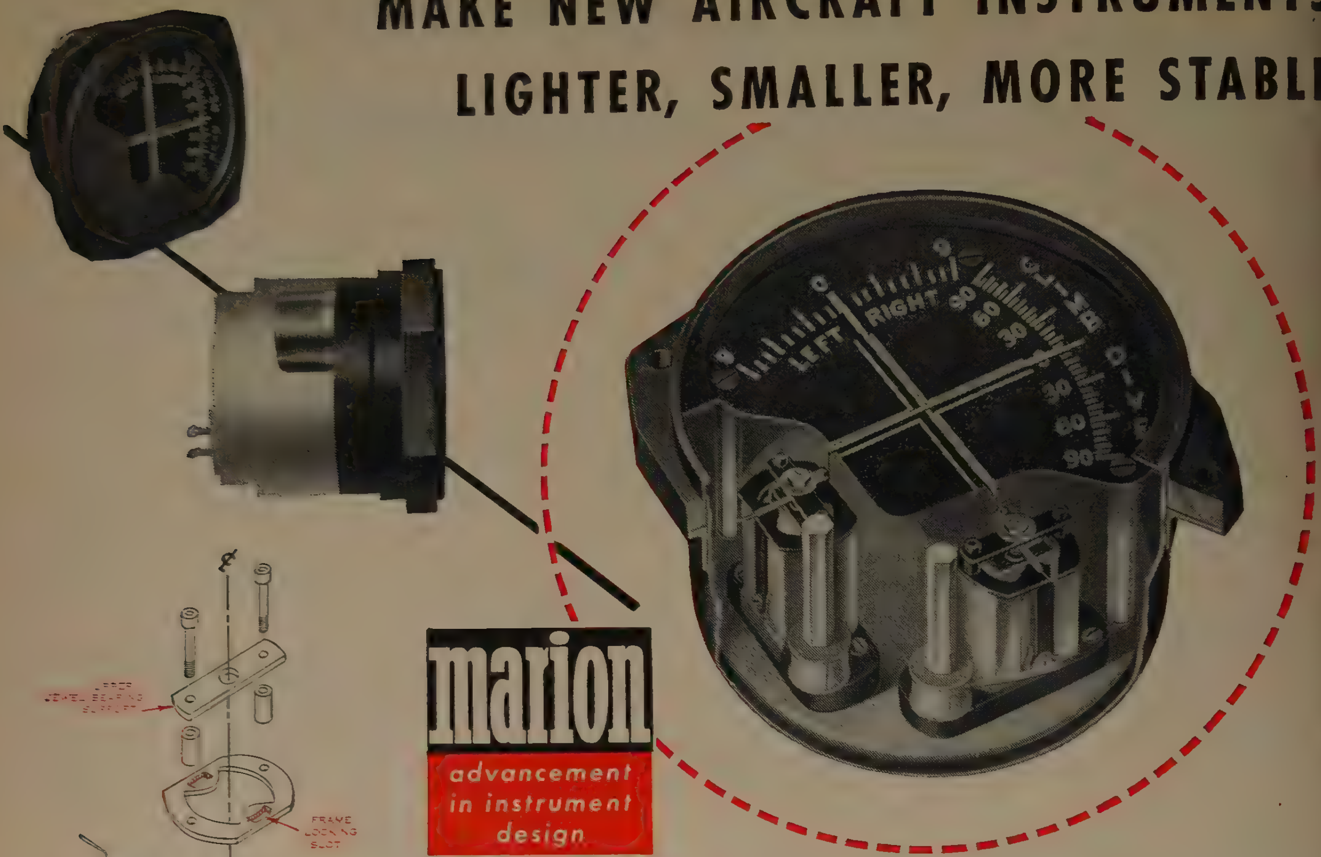
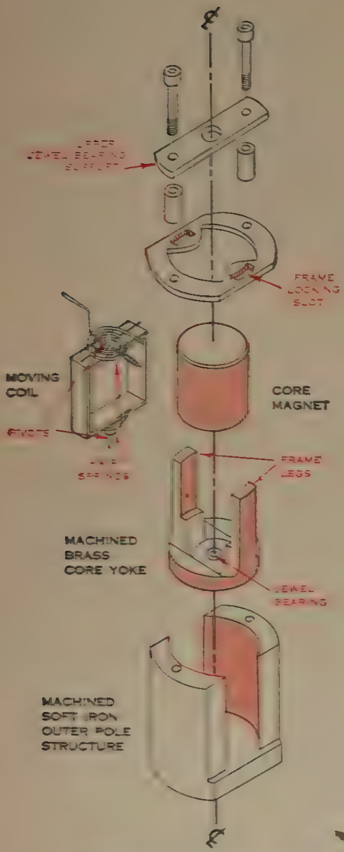
# MARION COAXIAL* MECHANISMS MAKE NEW AIRCRAFT INSTRUMENTS LIGHTER, SMALLER, MORE STABLE


LEFT
RIGHT
0
90
60
30
30
60
90

**marion**

*advancement in instrument design*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MOVING COIL
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HAIR SPRINGS
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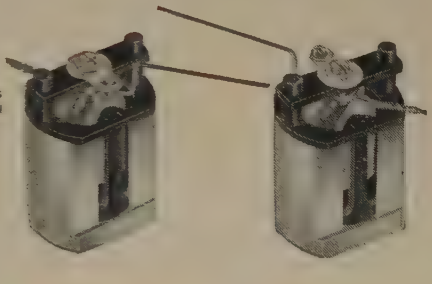
MACHINED BRASS CORE YOKE
JEWEL BEARING
MACHINED SOFT IRON OUTER POLE STRUCTURE

EXPLODED DIAGRAM SHOWING INTERLOCKING CONSTRUCTION
Marion coaxial mechanism

A new AN type multi-element aircraft instrument, incorporating recently developed Marion Coaxial Mechanisms, has greater durability and performance stability than many existing instruments of much greater size and weight. Applications of the new instrument, available with two, three or four elements, include ammeters, voltmeters, temperature indicators and radio navigational instruments. They meet the requirements of Army-Navy Aeronautical Design Standard AND10401 for 2¾″ dial instruments.

The Coaxial Mechanism making these improvements possible represents a new Marion concept in the mechanical design of moving coil mechanisms. The Coaxial assembly provides a self-shielded magnetic field of great strength, uniformity and stability. Ruggedness and stability are inherent in the basic simplicity of the design. Only two fasteners hold the rigid, interlocked assembly together. All critical dimensions are machined from a common center (the bearing axis), facilitating precise alignment of parts.



## MECHANISMS BY MARION

The Coaxial Mechanism typifies the way each Mechanism by Marion is designed to meet the particular requirements of a specific application — and to provide substantially improved performance, with large reductions in cube and weight. They are not adaptations or variations of standard, conventional mechanisms.

**Marion Electrical Instrument Company**
**407 Canal Street, Manchester, New Hampshire**

*Trade Mark        Patents Pending

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**THERMO-STATICALLY CONTROLLED TEMPERATURE REGULATING STAND**

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established 1894

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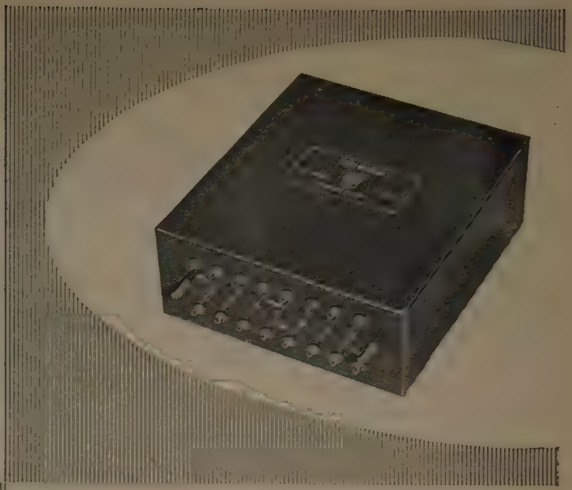
*this is a custom-made* delay-line by ESC*



*Custom-made to precise specifications, this unit replaces 1,423 feet of 75 ohm cable for variable delay equalization between television cameras and central studio console.

Our facilities are organized for design, development and production of delay lines in any quantity including Lumped Constant and Distributed Parameter.

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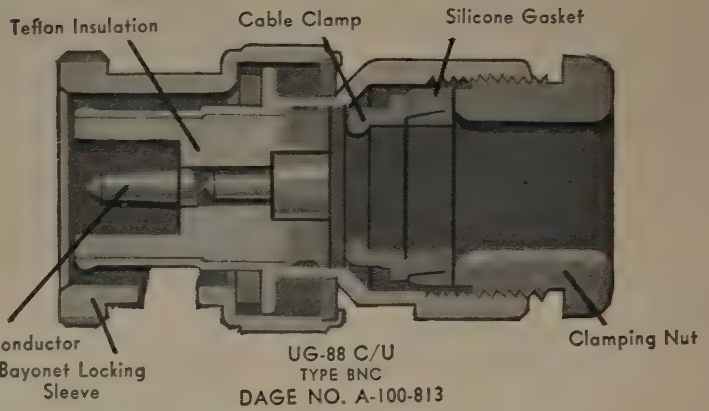

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# Ceramic Capacitors

**EVERY TYPE AND RATING FOR SMALL OR LARGE PRODUCTION RUNS!**

Sprague can provide you with the best capacitors for your requirements. And when it comes to ceramic capacitors, large plants with adequate production and tooling facilities offer prompt delivery for small or large production runs.

In the East, Sprague ceramic capacitors are made at North Adams, Mass., and Nashua, N. H. The Midwest is served by Sprague's wholly owned subsidiary, the Herlec Corporation of Grafton, Wis.

Some of Sprague's newest developments are shown at right. For future developments in ceramic capacitors, look to Sprague for the ultimate in performance, miniaturization, and reliability.

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Sprague, on request, will provide you with complete application engineering service for optimum results in the use of ceramic capacitors, and printed resistor-capacitor networks.

NEW!

### 'RING' CERAMIC CAPACITORS
to clean up chassis

SPRAGUE 2X6000-300
2X680-300

Designed to fit around 7-pin miniature tube sockets, these capacitors may contain 2, 3, or 4 sections. They result in a neat physical layout while reducing space to a minimum. Positive positioning of the ultra short leads between the capacitor and socket terminals eliminates lead dress problems and, consequently, allows "hot" circuit designs. Voltage ratings from 100 to 500 d-c. Write for Engineering Bulletin 610.

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simplify circuit design

SPRAGUE
4X.0039

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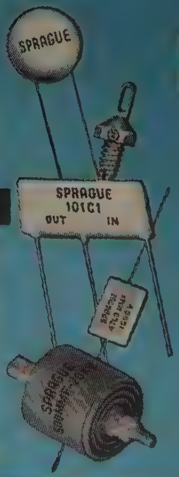
### WIDELY-USED CERAMIC CAPACITORS
for electronics, radio, and TV



Shown at left are a few of the many other types of ceramic capacitors available from Sprague. These include:

- Buttons
- Discs
- Hi-Voltage Moldeds
- Precision Ceramic Trimmers
- Plates
- Printed resistor-capacitor networks
- Hermetically sealed, metal cup and tubular precision capacitors

For complete details on any type of ceramic capacitor — it pays to ask Sprague. Write for catalog data on the types in which you are interested.

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NEW

PANORAMIC SPECTRUM ANALYZER SPA-1

now 50 mc to 4000 mc

WITH TWO TUNING HEADS

**Check these outstanding features:**
- Low noise input, less than 0.5 microvolts across 50 ohms, for high usable sensitivity
- 10 MC maximum sweepwidth, continuously reducible to 0 MC
- Continuously variable differential markers, ± 50 kc to ± 5 mc
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**Tuning Heads**

RF-2 50 mc-250 mc
RF-3 220 mc-4000 mc in five ranges

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- Panalyzor
- Panoramic Sonic Analyzer
- Panoramic Ultrasonic Analyzer

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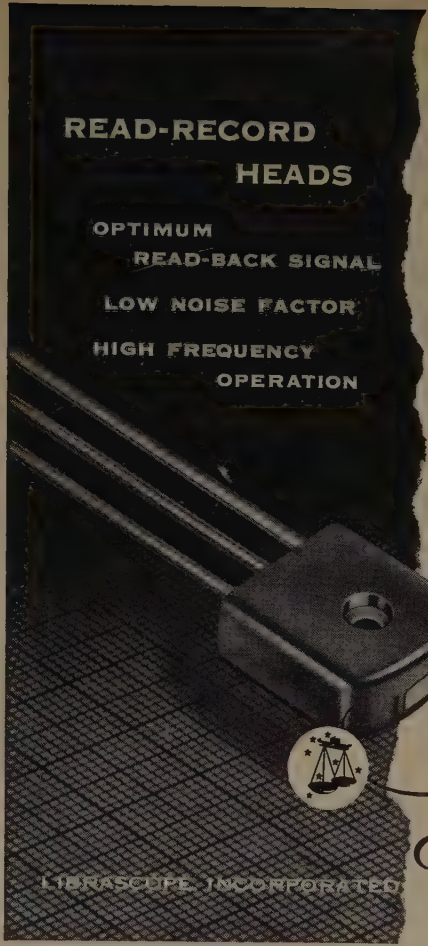

READ-RECORD HEADS

OPTIMUM READ-BACK SIGNAL

LOW NOISE FACTOR

HIGH FREQUENCY OPERATION

Librascope read-record heads are designed for recording and reading on magnetic drums or other magnetic storage systems and consist of a center-tapped coil wound on a toroidal core and molded into a temperature-stable epoxy resin package ¾″ long. Optimum read-back signal at high frequencies is made possible by sintered ferrite core, a winding with low distributed capacity and with back gap eliminated. Positioning dowel hole permits precise mounting. All heads subjected to 1200 volt RMS high potential test. Write for catalog.

SPECIFICATIONS:

Crosstalk limited to minus 60 Db for adjacent heads. Resonant frequency above 500 KC
Track width: .090 in.
Gap width: .0015 in.

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Must be familiar with audio and radio techniques. Instrumentation, transistor circuit design, and noise theory experience desirable.

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Must know pulse-radar techniques and servo mechanisms.

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Must have experience in the design of integrated test equipment employing radar and audio techniques.

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For system analysis and development.

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Microwave Equipment
Antennas
Infrared Equipment
Communications Equipment
Computers
Gyroscopes
Radar

- Liberal Hospitalization Plan
- Merit Salary Reviews
- Excellent Working Conditions
- Ideally located in Westchester County

●

Please telephone or send resume and salary requirements to the Personnel Department. All inquiries will be handled in confidence.

●

**THE NORDEN LABORATORIES CORPORATION**
121 Westmoreland Avenue
White Plains, New York
White Plains 6-4300

An assurance is required that the relocation of an applicant will not cause disruption of an urgent military project.

*Electrical Engineers*

*Mathematicians*

*Mechanical Engineers*

*Physicists*

The Ramo-Wooldridge Corporation, Los Angeles, is creating new positions in the research and development of

## Airborne Digital Computer Systems

*involving*

- ***SYSTEMS ANALYSIS***
- ***LOGICAL DESIGN***
- ***PROGRAMMING***
- ***TRANSISTOR CIRCUITS***
- ***CONVERSION DEVICES***
- ***MEMORY SYSTEMS***
- ***SUB-MINIATURIZATION***
- ***PACKAGING***

*Send inquiry to*

**The Ramo-Wooldridge Corporation**
DEPT. P-C, 8820 BELLANCA AVENUE,
LOS ANGELES 45, CALIFORNIA

Consideration must be given to whether relocation of applicant will disrupt other important military work.

# CAREER OPPORTUNITIES FOR . . .

- mechanical engineers
- electronics engineers
- electrical engineers
- physicists
- mathematicians
- aerodynamicists
- systems engineers

**SANDIA CORPORATION,** a subsidiary of the Western Electric Company, operates Sandia Laboratory under contract with the Atomic Energy Commission. Sandia engineers and scientists work at the challenging task of designing and developing atomic weapons. Graduate engineers and scientists, with or without applicable experience, will find excellent opportunities in the fields of component development, systems engineering, applied research, testing, and production.

**COMPENSATION** is competitive with that offered in other industry. Ingenuity and initiative are valued highly, and opportunities for professional advancement are outstanding. Working conditions are excellent, and employee benefits are most liberal.

**SANDIA LABORATORY** is located in Albuquerque — a modern, cosmopolitan city of 150,000, rich in cultural and recreational attractions and famous for its excellent year-around climate. Adequate housing is easily obtained. For descriptive literature giving more detailed information on Sandia Laboratory and its activities — or to make application for employment — please write:

**professional employment**
**division 1A**

**SANDIA** *Corporation*

**Sandia Base**
**Albuquerque, New Mexico**

# ELECTRICAL ENGINEERS

*or*

# PHYSICS GRADUATES

*with experience in*

## RADAR *or* ELECTRONICS

*or those desiring to enter these areas...*

*The time was never more opportune than now for becoming associated with the field of advanced electronics. Because of military emphasis this is the most rapidly growing and promising sphere of endeavor for the young electrical engineer or physicist.*

Since 1948 Hughes Research and Development Laboratories have been engaged in an expanding program for design, development and manufacture of highly complex radar fire control systems for fighter and interceptor aircraft. This requires Hughes technical advisors in the field to serve companies and military agencies employing the equipment.

As one of these field engineers *you will become familiar with the entire systems involved,* including the most advanced electronic computers. With this advantage you will be ideally situated to broaden your experience and learning more quickly for future application to advanced electronics activity in either the military or the commercial field.

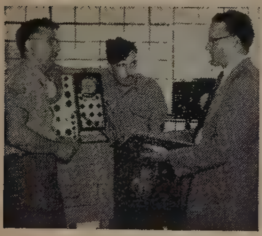
Positions are available in the continental United States for married and single men under 35 years of age. Overseas assignments are open to single men only.

*Scientific*
*and*
*Engineering*
*Staff*

**HUGHES**

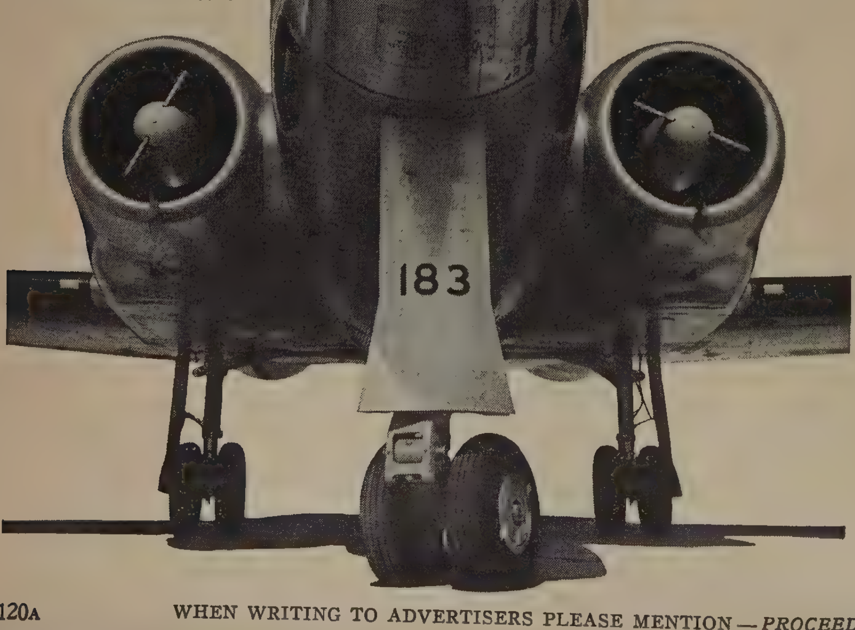
RESEARCH
AND
DEVELOPMENT
LABORATORIES

*Culver City,*
*Los Angeles*
*County,*
*California*



Hughes Field Engineer H. Heaton Barker (right) discusses operation of fire control system with Royal Canadian Air Force technicians. Avro Canada CF-100 shown at right.

Relocation of applicant must not cause disruption of an urgent military project.



# Positions Wanted By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The Institute publishes free of charge notices of positions wanted by I.R.E. members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The Institute necessarily reserves the right to decline any announcement without assignment of reason.

### ENGINEER

BSEE, Tau Beta Pi, 1951. Age 29, single. 3 years Navy Electronics Technician. 3 years experience in electronic circuit design and development. Desires position as application or sales engineer. Will relocate any place in east. Box 772 W.

### ENGINEER

BSEE with 2 years experience in fire control system calibration, 2 years in field service on computer, radar and hydraulic transmissions; 2 years U. S. Navy Electronic Technician. Desires position as sales engineer or manufacturer's representative. Age 28, married. Prefer west, south or midwest location. Box 773 W.

### SALES OR LIAISON ENGINEER

BEE 1948, 80% of MSc in applied mathematics to date; licensed professional engineer, N.Y. Age 30, married, one heir. 6 years diversified experience military comm. and electronics. Desires challenging sales or liaison opportunity. Salary requirement modest, secondary to large potential. Box 774 W.

### ENGINEER

BSEE Rensselaer Polytechnic Institute (Communications) 1950. Age 28, married. 2½ years Navy FC 2/c. 4 years field engineering experience with fire control. Communication and television equipments. Desires position with future in design or development work. Box 775 W.

### ELECTRONICS ENGINEER

BEE Polytechtnic Institute of Brooklyn 1954, age 32, married, veteran. 5 years field engineering and supervision (35) men, radio, radar and sonar systems, including classified projects; 2 years industrial electronics design and development; 3 years broad electro-mechanical experience. Desires development and/or production engineering position, N.Y. metropolitan area preferred. Box 776 W.

### SALES ENGINEER

BSEE, 10 years experience in all phases of military electronics. Desires a challenging opportunity in a sales capacity with aggressive firm. Metropolitan New York area. Box 778 W.

*(Continued on page 122A)*

WESTINGHOUSE CALLING...

# ELECTRONIC ENGINEERS

## WITH A DESIRE

# TO CREATE!

The chief requirement of advanced development work such as that now being conducted at the Westinghouse Electronics Division is a staff of experienced engineers with a keen desire to create!

Top-level positions in our expanding Electronics Division provide a challenge and opportunity for creative engineers.

Begin now to satisfy your desires . . . at Westinghouse. Current openings offer excellent income and employe benefits, as well as ideal working conditions. You will have no difficulty finding comfortable suburban living accommodations.

## CURRENT OPENINGS INCLUDE:

**ELECTRONIC CIRCUIT ENGINEERS (MILITARY)**
Applied research, development and design of electronic apparatus for communications, radar and missile guidance systems.

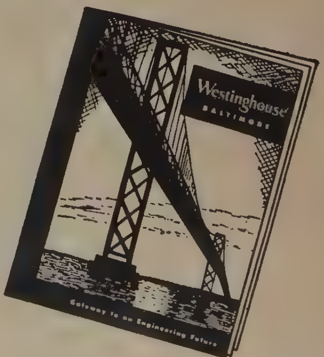
**VHF COMMUNICATIONS ENGINEERS**
Applied research, development and design of military VHF communications apparatus at all power levels for both transmitters and receivers.

**ANTENNA AND WAVEGUIDE ENGINEERS**
Applied research, development and design of antennas and waveguide systems for military communications and radar equipment.

**RADAR INDICATOR SYSTEMS ENGINEERS**
planning, studying, proposing, and applied research, development, design to include search, fire-control and missile guidance systems.

***For Confidential Interviews . . .***

Send a letter outlining your education and experience to:
R. M. Swisher, Jr., Employment Supervisor, Dept. 31
Westinghouse Electric Corp.
2519 Wilkens Avenue, Baltimore 3, Maryland
Illustrated brochure will be promptly forwarded
to all qualified applicants



**YOU CAN BE SURE...IF IT'S Westinghouse**

SPECIAL OPPORTUNITIES FOR

**ELECTRONIC ENGINEERS**

Convair in beautiful, sunshiny San Diego invites you to join an "engineers" engineering department. Interesting, challenging, essential long-range projects in missiles, engineering research and electronics development. Positions open in these specialized fields:

**Microwave Antennae**
**Microwave Components**
**Electronic Packaging**
**Mathematical Physics**
**Electronic Components**
**Electronic Systems**
**Applied Mathematics**
**Transmitters & Receivers**
**Dynamics Testing**
**Telemetering**
**Servomechanisms**
**Electron Tubes**
**Radome Design**
**Digital Computers**
**Test Equipment**
**Miniature Circuits**

Generous travel allowances to those accepted. For free brochure, write Mr. H. T. Brooks, Engineering Dept. 800

**CONVAIR**
IN BEAUTIFUL
**SAN DIEGO**
Division of General Dynamics
3302 PACIFIC HIWAY
SAN DIEGO 12, CALIFORNIA

## Positions Wanted

*(Continued from page 120A)*

### AUTOMATION ENGINEER

Capable engineer desires connection at management level with company doing automation work for itself or customers. Will consider consulting. Please describe situation in detail. Box 785 W.

### ELECTRONIC ENGINEER

BEE June 1954. 3 years U. S. Navy ETM 1/c. 1 year design and development; 5 years technical experience. Desires future. Will relocate. Box 786 W.

### ENGINEER

BSEE, MSEE, age 28, married, one child. Graduate work in mathematics, servomechanisms, feedback amplifiers. 2 years electronic work in Army; 2 years university instructor; 2 years circuit development and design; 2 years system Project Engineer on classified Government contract. Desires responsible position in Philadelphia metropolitan area. Box 787 W.

### ELECTRICAL ENGINEER

BEE 1948, MEE 1951. Age 30, married, 3 children. 5 years research and development experience in microwaves, plus 1 year as Chief Engineer. Desires responsible position with well-established firm. Interested in New York-New Jersey area. Box 788 W.

### ENGINEER

BS in engineering physics. 3 years as engineer in electronics development and design, product engineering and technical writing. Will be released from service this winter. Desires work abroad. Age 25. Married. Box 789 W.

### SYSTEMS ENGINEER

BEE degree, age 32. 8 years engineering experience; electromechanical development, instrumentation, environmental control on guided missiles and photo-reconnaissance systems; all phases of industrial engineering including incentive programs and cost analysis. Desires supervisory position in New York area utilizing above knowledge. Box 790 W.

### ENGINEER

BEE 1951, age 29. 3½ years Project Engineer on classified R & D electronic fire control systems and equipment, radar and infrared; 3 years Radar Officer, U. S. Navy; Varied experience in design and production. 1 year LLB. Postgraduate courses in EE. Desires position in R & D, or application. Willing to learn and relocate. Box 791 W.

### ENGINEER (No License)

Graduate of Brooklyn High School of Auto Trades and R.C.A. Institutes. Want position with future; Can work in conjunction with engineering staff in electronics and mechanical fields. Married, age 30. Veteran. Box 792 W.

### ENGINEER

BS in Mil. Engineering, MS in Com. Engineering, Ph.D. in Electrical Engineering. Specialized in network theory, circuit design, filter design, transit analysis. Desires association with consulting engineering firm in anticipation of eventual retirement from Government service. Prefer northern New Jersey location. Box 793 W.

*(Continued on page 124A)*

# RCA NEEDS ENGINEERS

## who won't be held back!

RCA, world leader in electronics, has career opportunities for qualified ELECTRICAL and MECHANICAL ENGINEERS . . . PHYSICISTS . . . METALLURGISTS . . . PHYSICAL CHEMISTS . . . CERAMISTS . . . and GLASS TECHNOLOGISTS for long range work in military or commercial fields.

### SYSTEMS—ANALYSIS—DEVELOPMENT —DESIGN—APPLICATION ENGINEERING

*in the following fields:*

**AVIATION ELECTRONICS (FIRE CONTROL, PRECISION NAVIGATION, COMMUNICATIONS)**—Radar—Analog Computers—Digital Computers—Servo-Mechanisms—Shock & Vibration—Circuitry—Heat Transfer—Remote Controls—Sub-Miniaturization—Automatic Flight—Transistorization—Automation

**RADAR**—Circuitry—Antenna Design—Servo Systems—Information Display Systems—Gear Trains—Stable Elements—Intricate Mechanisms

**COMPUTERS**—Digital and Analog—Systems Planning—Storage Technique—Circuitry—Servo-Mechanisms—Assembly Design—High Speed Intricate Mechanisms

**COMMUNICATIONS**—Microwave—Aviation—Mobile—Specialized Military Systems

**MISSILE GUIDANCE**—Systems Planning and Design—Radar and Fire Control—Servo-Mechanisms—Vibration and Shock Problems—Telemetering

**COMPONENT PARTS (COLOR & MONOCHROME TV)**—HV Transformers—Coils—Deflection Yokes

**SEMI-CONDUCTORS**—Transistors—Diodes

**ELECTRON TUBE DEVELOPMENT**—Receiving—Transmitting—Cathode-Ray—Phototubes and Magnetrons—Power Tubes—Camera Tubes

**ELECTRONIC EQUIPMENT FIELD ENGINEERS**—Specialists for domestic and overseas assignment on military electronic Communications, Navigational Aids, and Guided Missiles.

At RCA you'll work in an atmosphere conducive to creative work—laboratory facilities unsurpassed in the electronics industry . . . constant association with leading scientists and engineers.

Positions now open in Systems, Analysis, Development, Design and Application Engineering. Your choice of long range work in commercial or military fields.

Delightful suburban living easily available. Modern retirement program . . . liberal tuition refund plan for advanced study at recognized universities . . . modern company paid benefits for you and your family.

Individual accomplishments readily recognized. Ample opportunities for increased income and professional advancement.

Join the team at RCA and grow with the world leader in electronics.

*Personal interviews arranged in your city.*

Please send complete resume of your education, experience, and specialized field preference to:

**MR. JOHN R. WELD**
**Employment Manager**
**Dept. 302L**
**Radio Corporation of America**
**30 Rockefeller Plaza, New York 20, N.Y.**

RCA ®

**RADIO CORPORATION of AMERICA**

# RAYTHEON'S MISSILE AND RADAR DIVISION

Bedford, Mass.

## CAREER ENGINEERING POSITIONS AVAILABLE

- **SENIOR RADAR SYSTEMS ENGINEER**
  Must have detail design experience in field of electronics with some general experience in radar applications and radar systems engineering. Must be capable of undertaking senior responsibility in important projects. Minimum of five years' applicable experence required.
- **SENIOR RF ENGINEER**
  Opening for a practical engineer with initiative and appropriate background. Primarily must have extensive experience in microwave techniques, with some experience and know-how in Radar Systems. Must possess keen appreciation of the RF requirements of radar systems to meet military specifications. Minimum of five years' applicable experience required.
- **SENIOR MECHANICAL ENGINEER**
  Must have experience in the design of mechanical components such as gear trains, hydraulic actuators, mechanical drives, gimbals, and related components for airborne systems. Must possess good working knowledge of machine practices, machine tools and their uses. Desirable to have knowledge of servomechanisms and electrical drives for ground and airborne systems. Minimum of five years' applicable experience required.
- **MECHANICAL ENGINEERS (Junior and Senior Level)**
  Experience in the design of one or more of the following categories required: Electro-mechanical components, small motors, hydraulic components, precision bearing design, servomechanism (hydraulic), instruments. Minimum of four years' experience required.
- **PLASTICS ENGINEER**
  Minimum of two years' experience required in physical chemistry, preferably with work on plastic materials. Duties involve the deevlopment of techniques using high temperature plastics for mounting and embedding electronic components. Must be capable of developing molds and predicting suitability of chosen plastics and finishes for electronic components.
- **ENGINEERING PHYSICIST (RADOMES)**
  Should have degree in Physics (or Electrical Engineering with proficiency in physics and mathematics). Two to five years' experience required in appropriate areas of physics and/or electronic engineering in circuit design, RF design, and related developments. Knowledge of dielectric properties of radome materials and experience or know-how in microwave techniques desirable.
- **ELECTRONICS ENGINEER**
  Must have three to five years' experience in the design and engineering of centimeter radars. Additional experience in Field or military electronics and aircraft installations desirable.
- **CIRCUIT DESIGN ENGINEERS**
  Several openings for engineers with a minimum of three years' experience in circuit design work.
- **HEAT TRANSFER ENGINEER**
  Four to five years' experience required in cooling techniques and heat transfer design of electronic equipment for use in Guided Missiles and Airborne Radar Systems.
- **DESIGN ENGINEER**
  Three to five years' experience required in Ground-to-Air Missile launching equipment and/or field experience with intimate knowledge of missile handling equipment.

RAYTHEON'S MISSILE AND RADAR DIVISION is a well-established, progressive organization located 20 miles from Boston, an area offering excellent housing, recreational and educational facilities.

*Please write, giving full particulars concerning education, experience, and salary to Personnel Division*

**RAYTHEON MANUFACTURING COMPANY**
*190 Willow Street, Waltham, Mass.*

## Positions Wanted

*(Continued from page 122A)*

### ENGINEER

BSEE (Communications) 1952, age 26, married. U. S. Navy Aviation Electronics Technician Experience in application engineering. Desires position in application or sales engineering. Resume on request. Box 794 W.

### ELECTRONIC—PRODUCT ENGINEER

BEE 1951. Age 33. 13 years in electronics. Design, development, production on fire and missile-control radar systems. Video, servo, CRT, data transmission, systems integration, human engineering. Liaison between engineering and production. Supervisory and some administrative experience. Self-starter and neck sticker-outer when expediency requires. Seeks position slightly over his head. Will relocate. Present income $9,000. Box 802 W.

### ELECTRONIC ENGINEER

BEE, MS. 5 years electronic engineering experience. Pulse circuits, microwave, radar development. 1 year technical writing. Desires position in electronic research and development. New York City area preferred. Box 803 W.

### SALES ENGINEER

BEE. Age 27, married. 4 years experience in Military electronics, including 2 years Application Engineer in aviation electronics. Desires a challenging opportunity in a sales capacity. Metropolitan New York area. Box 804 W.

### ENGINEER

Twenty-seven years a technical writer and editor on a New York newspaper. Wants public relations, publicity or technical writing-editing job in electronics. Preferably in New York area. Box 805 W.

---

## POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. ....

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
I East 79th St., New York 21, N.Y.

### APPLICATIONS ENGINEER

Leading manufacturer of electronic test and measuring equipment has openings in technical sales work for aggressive, young engineering graduate. Experience with test equipment desirable but not essential. Excellent opportunity with long-established company; location New England. Write in confidence. Box 788.

*(Continued on page 126A)*

*An Opportunity*

is offered for intelligent, imaginative engineers and scientists to join the staff of a progressive and self-sustaining, university-affiliated research and development laboratory.

We are in need of men interested in:

- RADAR DESIGN AND APPLICATIONS
- COMPUTER DESIGN
- MISSILE GUIDANCE
- COMMUNICATIONS

Salary structure and benefit programs are on a par with industry. In addition, there are many tangible advantages, such as our self-sponsored internal research policy, of interest to men with ingenuity and initiative.

CORNELL AERONAUTICAL
LABORATORY, INC.
BUFFALO 21, NEW YORK

---

MICROWAVE ENGINEERS

For advanced development engineering in X, S and L band for coaxial and wave guide components, covering printed circuits, ferrites, pulse and CW doppler and countermeasure systems.

Permanent, creative positions with one of the fastest growing electronics laboratories in America (organized, owned and run by engineers) where the only limitations are one's own initiative and ability.

Live and work in beautiful New Hampshire, vacation spot of the East—and only one hour from Boston with its wealth of cultural and educational facilities.

Please submit resumes, including initial salary requirements, to Mr. Donald Clement.

SANDERS ASSOCIATES
INCORPORATED
NASHUA, NEW HAMPSHIRE

---

**Electronics Research Engineer Irving Alne** records radiation antenna patterns. Twenty-two foot plastic tower in background minimizes ground reflections, approximates free space. Pattern integrator, high gain amplifier, square root amplifier and logarithmic amplifier shown in picture are of Lockheed design.

Antenna development program at Lockheed expands

Lockheed's diversified development program presents Electronics Engineers qualified for airborne antenna design with a wide range of assignments in communication, navigation and microwaves. Antenna design is one of the fastest growing research and development areas at Lockheed.

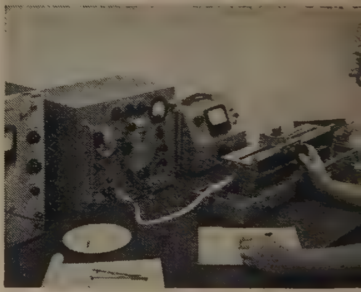
Studies embrace virtually all types of aircraft, including the Super Constellation radar search plane—a type of aircraft developed and produced exclusively by Lockheed.

Career Positions at Lockheed

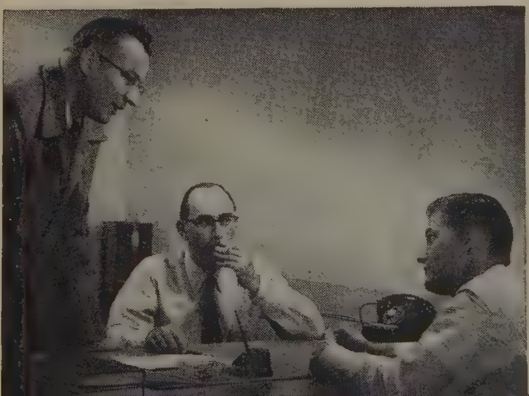
Lockheed's expanding development program has created a number of positions for Electronics Engineers and Physicists to perform advanced work in antenna design.

Lockheed offers you increased salary rates now in effect; generous travel and moving allowances; an opportunity to enjoy Southern California life; and an extremely wide range of employee benefits which add approximately 14% to each engineer's salary in the form of insurance, retirement pension, sick leave with pay, etc.

Those interested are invited to write E. W. Des Lauriers, Dept. IRE-12, for a brochure describing life and work at Lockheed and application form.



**Electronics Research Engineer F. R. Zboril** measures input impedance of a scale model helical antenna array used for ground tracking of missiles. Most of Lockheed's other antenna work involves advanced research studies on flush mounted antennas.



**E. O. Richter**, Electronics Research department manager (seated), W. R. Martin, antenna laboratory group engineer (standing), and J. L. Rodgers, electronics research engineer, discuss design of corrugated surface antenna.

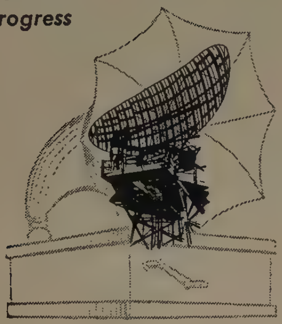
LOCKHEED
AIRCRAFT CORPORATION
BURBANK
CALIFORNIA

**ENGINEERS**

**with EXPERIENCE**

**in electronic development**

*with experience comes progress*



*are you EXPERIENCED in*
RADAR - MISSILE CONTROL
AIRBORNE COMMUNICATIONS
MOBILE COMMUNICATIONS
AUTO RADIO

. . . does an analysis of your background show that — at present — you are employed at THE HIGHEST LEVEL OF YOUR SKILL?

***. . . Send us a resume of your background. We may have a higher level position open for you!***

Send resume to Mr. L. H. Noggle, Dept. M-

**BENDIX RADIO**

Division of Bendix Aviation Corp. Baltimore-4, Md.

**ENGINEERS**

*looking for . . .*

*. . . a good start?*

*. . . rapid development of your professional skill?*

**You can have both at Sperry,**

**PIONEERS IN A WIDE RANGE OF FIELDS, FOR MORE THAN 43 YEARS**

We invite you to investigate the exceptional employment opportunities available on our unusually large research, design, and development staff, in many fields including the following:

Klystron & traveling tube research • Analogue & digital Computers • Radar • Hydraulics • Communication Equipment • Pulse Transformers • Servo Mechanisms • Electronic Circuits • Aircraft Controls • Instrumentation • Fractional H.P. Motors • Magnetic Amplifiers • Radio Frequency & Microwave Measurement.

*PUBLICATIONS ENGINEERS To write manuals and engineering reports.*

Advanced and challenging assignments • Association with top Engineers • Interesting, diversified work • Remuneration based on professional abilities • Modern plant—latest laboratory facilities • Adequate housing • And of course, employee benefits, and congenial surroundings, among the finest.

*Please submit resume to our Engineering Personnel Section. (Personal interviews may be arranged in your city.)*

**SPERRY GYROSCOPE CO.**
Division of the Sperry Corp.
Great Neck, Long Island, N.Y.

## Positions Open

*(Continued from page 124A)*

### ENGINEERS—PHYSICISTS

The Air Force urgently needs civilian electronic engineers and physicists. If you have experience or training in electronic research and development or in the installation and maintenance of fixed plant facilities, apply now! Salaries range from $3410 to $9600 per annum. Free on-the-job graduate degree training is offered by Syracuse University, College of Engineering. Address Professional Recruiting Officer, Griffiss Air Force Base, Rome, New York.

### RECTIFIER ENGINEER

Degree, under 35, with minimum of 2 years actual experience in process and manufacture of metallic rectifiers. Salary commensurate with experience. Long established firm located in suburban Pittsburgh, Pa. Submit résumé to Box 789. All replies confidential.

### ELECTRONIC ENGINEERS

Junior and Senior Electronic Engineers with experience, who are interested in test work, research, design and development projects in America's foremost testing organization are invited to send full particulars, including salary requirements to the Personnel Dept. United States Testing Co., Inc., 1415 Park Ave., Hoboken, New Jersey.

### MICROWAVE ENGINEER

To head a group engaged in system and component development in Research and Development Dept. An advanced degree and industrial experience are required. This position offers an excellent opportunity for growth with a small established company in suburban Boston. Please reply to Robert L. Blanchard, Chief Research Engineer, Trans-Sonics, Inc., Bedford, Mass.

### ELECTRONIC ENGINEER

Small progressive western firm desires engineer with experience in electronic computers. Please write giving education and experience to Box 382, San Pedro, Calif.

### ENGINEER

Engineer with academic and considerable practical background in electronics and communication circuit design to do development work on complex military electronic systems. Unusual opportunity for advancement and growth in this newly organized development staff. Address reply to Box 791.

### RADAR DEVELOPMENT AND DESIGN

Electronic circuits, microwave circuits and antennas and mechanical design of mechanisms for electronic equipment. Minimum requirements, degree and 2 years experience in radar or allied field. Suburban Los Angeles location. Canoga Corporation, Box 550, Van Nuys, Calif. Tel. STanley 7-1156.

### JUNIOR INSTRUCTOR

Junior Instructor, technical electricity to teach courses in mathematics at the technical institute level. Salary $4,500.00. Location, central New York state. Box 792.

*(Continued on page 128A)*

Engineers

TUNED TO TOMORROW

If you are an engineer who thinks in terms of tomorrow... who has the ability and drive to move ahead professionally but finds advancement slow-going in a large, impersonal organization...then it's time you knew about us and the opportunities we offer. National Company, Inc. is a quality pioneer in the electronics industry with steady and sound growth over the past forty years.

Our eyes are on the future. If you are interested in growing along with us, you are invited to apply for any of the following positions:

MECHANICAL

**Design Engineers** — B.S.M.E. Projects related to analog and digital computers, radar and electronic counter devices.

**Designer** — For electronic equipment, such as transmitters, receivers, radar, computers, etc.

ELECTRONIC & ELECTRICAL

**Project Engineers**—B.S.E.E. Electronic circuit development and design for communication frequencies and above.

**Product Designers**—B.S.E.E. Receiver engineering, binary counter knowledge or transmitter exciter experience.

**Development Engineer** — B. S. E. E. and/or Physics. UHF transmitter and/or receiver development. Knowledge pulse circuitry and transistor circuitry.

**Electronic Engineers** — B.S.E.E. Designing and following units through production and formulating procedures.

**Electrical Engineer** — Minimum B.S.E.E.; M.S.E.E. preferred. UHF and/or microwave circuit design and feedback technique.

PHYSICIST

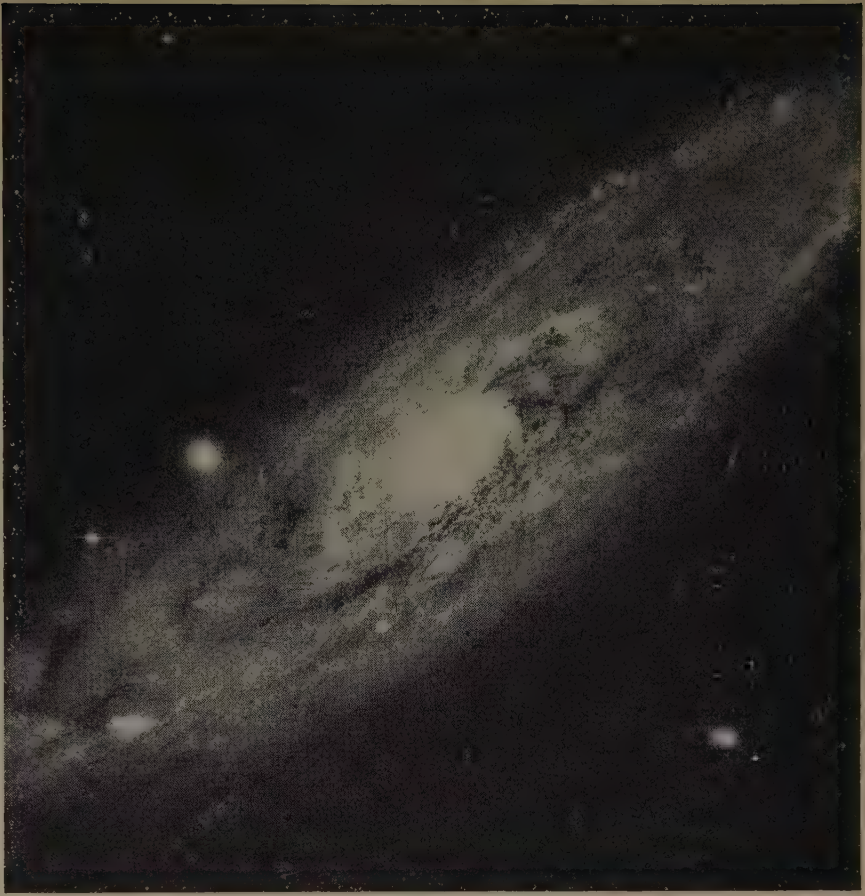
**Experimental Physicist** — M.S. or equivalent. Minimum 1 year solid state gas discharge and some vacuum systems experience.

*You will have the opportunity to qualify for excellent salaries commensurate with your ability and experience, plus National's liberal fringe benefits.*

Please forward complete resume to:
**Mr. James R. Keskula**
Employment Manager

National
NC EST. 1914

NATIONAL COMPANY, INC.
61 Sherman St. Malden, Mass.



**target tomorrow**

As a major development in its pace-setting program of advance planning, the Martin Aircraft Company is now in the field of nuclear power.

This means that a top team of scientists, physicists and engineers is being assembled at Martin to carry on a planned, long-range program in this tremendous new science.

Never before in our industry has there been such an opportunity for a select group of qualified people.

They will be the nucleus of a major undertaking in the horizonless science of atomic energy.

Write to J. M. Hollyday, Department P-12, The Glenn L. Martin Company.

MARTIN
BALTIMORE · MARYLAND

# ENGINEERS

## ELECTRONICS BACKGROUND

A few responsible positions available for systems work associated with navigational computers.

The modern facilities and congenial atmosphere at Kollsman, designers of America's finest aircraft instruments, provide an environment conducive to truly creative work.

Please submit resumes to Employment Manager. Interviews will be arranged for qualified applicants.

KOLLSMAN INSTRUMENTS

**KOLLSMAN Instrument Corp.**

80-08 45th Ave.
Elmhurst, L.I., New York

**WHITE-RODGERS ELECTRIC COMPANY**

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Are Commanding Wide-Spread Attention and Interest
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of this
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Mechanical Design
Test Instrumentation
Electronics Packaging
Circuit Design

Send Resume To Employment Manager
1201 Cass Avenue, St. Louis 6, Mo.

# Positions Open

*(Continued from page 126A)*

### ELECTRICAL—ELECTRONICS DESIGN ENGINEERS

**(Long Range Program—Aircraft Trainers)**

Challenging, creative assignments in an expanding and progressive organization. BSEE plus experience in electro-mechanical devices, servomechanisms or analogue computers desirable. Send résumé to Stanley Aviation Corp., Buffalo Municipal Airport, Buffalo 25, New York.

### BROADCAST AUDIO AND PHASOR DESIGN ENGINEERS

Immediate openings in expanding engineering department for men experienced in audio or phasor designing. Complete employee benefits. Salary open. Send complete details and photo to Gates Radio Company, Quincy, Illinois. Att: Mr. Roger M. Veach, Personnel Division.

### ELECTRONIC ENGINEERS—MECHANICAL ENGINEERS

Openings are available for Electronic Engineers with a minimum of 5 years experience in circuit design with primary emphasis on pulse circuitry and high frequency RF technique. Openings also exist for Mechanical Engineers with a minimum of 5 years experience in packaging electronic equipment as well as in mechanical design of small electro-mechanical devices. Send complete résumés to Mr. J. K. Delano, Exec. Vice Pres. Applied Science Corp. of Princeton, N.J., P.O. Box 44, or call Plainsboro 3-4141.

### ENGINEERS

Several positions for Electrical Engineers available in the development engineering group of a small growing engineering and manufacturing company. Circuit design experience is essential as the type of work will entail (1) Originating a detailed circuit design to meet written specifications, (2) Testing a breadboard of the proposed circuit to obtain performance characteristics. Experience with any of the following phases will be helpful: radar, computers, simulators, cathode ray displays, industrial automatic controls. Send résumé to Penn-East Engineering Corp., Box 240, Kutztown, Pa.

### INSTRUCTOR

California State Polytechnic College has one immediate opening for an instructor in the Electronic Engineering Dept. to teach courses in fields, waves, and antennas. Starting salary $4500 to $5000 for the academic year. Application may be made to Harold P. Hayes, Dean of Engineering, San Luis Obispo, Calif.

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Challenging positions for Electrical Engineers with experience in electronics design. Live in attractive small town with the opportunity of taking graduate work at the Pennsylvania State University. Reply to Personnel Officer, Haller, Raymond and Brown, Inc., State College, Pennsylvania.

### ELECTRICAL ENGINEER

Graduate Electrical Engineer familiar with pulse systems to act as sales representative in Los Angeles and vicinity. Send résumé. Box 793.

*(Continued on page 130A)*

## NEW HORIZONS

Today's horizons in electronic engineering are limited only by the vision of the individual himself. To those qualified men who desire to stand on the constantly changing frontiers of electronic development, we offer a chance to pioneer and grow with a soundly-established, yet young and progressive company.

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**Local and Field Assignments Available**

At least 5 years' experience in any *one* of these fields: Servo Mechanisms; Special Weapons; Microwaves; Antennas; Circuit Design; Flight Simulators; Radio Propagation; Electronic Computers and Communications.

Qualified to instruct in the operation and supervise installation, maintenance and repair of Radar, Sonar, Flight Simulators and allied electronic equipment in the field.

Salary and advancement commensurate with ability; liberal vacation, sick leave, 9 paid holidays, group life, sickness and accident insurance plans, and a worthwhile pension system.

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*Personnel*

Applicants should have at least a Bachelor's degree in Physics, Mathematics or Engineering and a minimum of one year direct experience with electronics analog computers. This experience may be in computer design, application or operation.

Our computer installation is well-equipped and expanding with important work on the complex dynamics and control problems characteristic of modern high-performance aircraft and guided missiles.

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WITH
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Section Heads, Engineers-in-Charge, Senior Engineers, Engineering Specialists and Junior Engineers for Research, Design, Development and Product Design on complex subminiaturized airborne electronic equipment and computers, experienced in:

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- Equipment Specifications
- F. M. Techniques
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- Heat Transfer
- Shock & Vibration
- Technical Writing
- Analytical Problems
- Antenna Design
- Applied Physics
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- Component Analysis & Testing
- Component Specifications
- Digital Computer Circuits & Systems
- Mechanical Design

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**SYLVANIA**
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## Positions Open

(Continued from page 128A)

### ELECTRONIC ENGINEERS AND ELECTRONIC SCIENTISTS

The Naval Research Laboratory has need for Electronic Engineers and Electronic Scientists in positions paying from $3410 to $7040. These vacancies involve such work as the design and development of admittance and impedance measuring apparatus; design and development of microwave components and transmission lines for radar; design and development of instruments relating to sonar equipment; design of networks and circuitry. etc. Reply to Dr. W. G. Torpey, Personnel Officer, Code 1817, Naval Research Laboratory, Washington 25, D.C.

### ELECTRONICS ENGINEER

Opportunities in product development, manufacturing or applications engineering for men with a degree in EE or physics and 2-5 years experience in any of these fields with a company engaged in manufacture of precision power supplies. Send résumé to Personnel Dept., Sorensen & Company, Inc., 375 Fairfield Ave., Stamford, Conn.

### ASSOCIATE PROFESSOR

Expansion of a young midwestern technical College requires the addition, by September 1955, of an Assistant or Associate Professor to instruct in electronics, communications and servomechanisms. MSEE degree and teaching or research experience are minimum requirements. Rank and salary open. Send summary of qualifications and background to Fournier Institute of Technology, Lemont, Illinois.

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For transistor or circuit design and product evaluation. One year in transistor circuit design, plus 4 years general vacuum tube circuit design experience. Knowledge of transistor theory essential.

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Graduate B. Ch. E. preferred, for transistor and diode production. Will consider other engineering degrees. Production background in semi-conductors or vacuum tube manufacturing desirable. Also, opportunity for one engineer to take charge of night shift.

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Experienced in design of pulse and radar systems to government specifications. Must be creative, mature and capable of assuming complete responsibility from project inception to production

**Send resume to: S. Winston, Personnel Mgr.**
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Submit resume or address request for personal interview to D. Bellat, Personnel Director.

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Scientific Personnel Office

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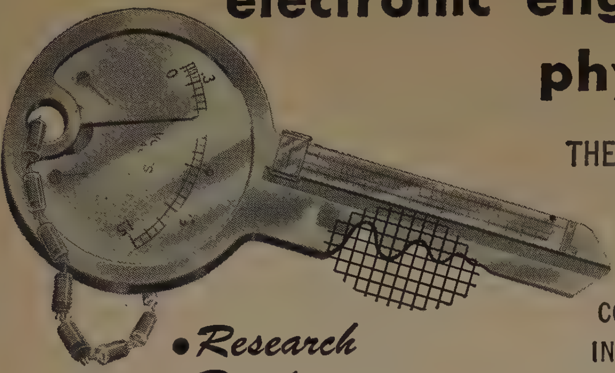

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**Detroit Controls Corporation**
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**ELECTRONIC ENGINEERS**

Our company has two vacancies for experienced research and development engineers in the general field of radar and microwave circuits. Candidates should be capable of independent work and would be employed on a challenging project. Salary commensurate with experience. Our laboratories are located in a residential suburban district west of Chicago. On contacting us please send the summary of your experience.

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**Stromberg-Carlson Company**
**Rochester 3, New York**

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A small aircraft instrument division of a major manufacturer of diversified equipment has an opening for an electronics engineer with 6 to 7 years experience in the field of servo-mechanisms and related work.

The duties are concerned with the design and development of vacuum tube, magnetic and transistor circuits and their application in systems.

The ability to follow through from the planning stage to the final product is essential. The position also requires the supervision of a group of engineers, and coordination with model shop and drafting sections. An EE degree with a major in electronics is desirable.

The location is in New Jersey adjacent to metropolitan New York City. Please submit complete details, in confidence, including initial salary required.

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These positions require the ability to manage a comprehensive design and development engineering organization and to plan broad engineering programs. Your ability should be substantiated by proven supervisory experience and a degree in EE, ME, or Physics.

*Send a complete resume of your education and experience to:*

**Mr. John R. Weld, Employment Manager**
**Dept. B-453L, Radio Corporation of America**
**Camden 2, New Jersey**

**RADIO CORPORATION OF AMERICA**

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## Electronic Engineering Company *of California*

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## 3 CM. ECHO BOX RF 3/AP

Cavity has a "Q" of 30,000 and is tuned by means of an internal 24 vdc motor. Unit is tunable over a range of 80 mc. When motor is left on, the tuning plunger goes thru the tuning range three times per minute. During the tuning motion, an eccentric cam on the mechanism causes an additional flutter action of the tuning disk at approximately 200 cycles per minute. This flutter range curves about 15 mc. This eliminates need of stopping the motor at the peak of the signal, and also gives a characteristic pattern to the echo signal. Input is to type "N" input jack ..**$125.**

## MICROWAVE COMPONENTS

### 10 CM.—RG48/U Waveguide

**10CM ECHO BOX:** Tunable from 3200-3333 Mc. For checking out radar transmitters, for spectrum analysis, etc. Complete with pickup antenna and coupling devices. ....................$27.50

**10 CM ANTENNA ASSEMBLY:** 3000-3300 Mc. Parabolic Dish, 29 inch Diam. Fed from dipole **Rotation:** 360 Deg. Azimuth at speeds of 20 and 10 RPM. **Tilt:** 20 deg. above and below horizontal. Motor-Driven by 2-28V motors, 4.5 A Total drain. Azimuth info. is fed to selsyn mechanism, and elevation data is obtained from Azimuth potentiometer. Net weight 65 lbs. ............$78.50

**POWER SPLITTER** for use with type 726 or any 10 CM Shepherd Klystron. Energy is fed from Klystron antenna through dual pick-up system to 2 type "N" connectors .........$22.50 EACH

**LHTR, LIGHTHOUSE ASSEMBLY.** Parts of RT39 APG 5 & APG 15, Receiver and Trans. Cavities w/assoc. Tr. Cavity and Type N CPLG, To Recvr. Uses 2C40, 2C43, 1B27, Tunable APX 2400-2700 MCS. Silver Plated ..........$22.50

**BEACON LIGHTHOUSE** cavity p/o UPN-2 Beacon 10 cm. Mfg. Bernard Rice, each ........$27.50

**MAGNETRON TO WAVEGUIDE** Coupler with 721-A Duplexer Cavity, gold plated ......$45.00

**721A TR BOX** complete with tube and tuning plungers ..................................$12.50

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**AS14A AP-10 CM** Pick up Dipole with "N" Cables ..................................$4.50

**HOLMDELL-TO-TYPE** "N" Male Adapters, W. E. #D167284 ................................$2.75

**I.F. AMP. STRIP:** 30 MC, 30 d.b. gain, 4 MC Band-width, uses 6AC7's—with video detector, A.F.C. less tubes ............................$24.00

**BEACON ANTENNA,** AS31/APN-7 in Lucite Ball. Type "N" feed ..........................$22.50

**ANTENNA, AT49A/APR:** Broadband Conical, 300-3300 MC Type "N" Feed ...........$12.50

**"E" PLANE BENDS,** 90 deg. less flanges ...$7.50

### 3 CM.—RG 52/U Waveguide

**3 CM ANTENNA ASSEMBLY:** Uses 17" paraboloid dish. operating from 24 vdc motor. Beam pattern: 5 deg. in both Azimuth and elevation. Sector Scan: over 160 deg. at 35 scans per minute Elevation Scan: over 2 deg. Tilt: Over 24 deg. ..............................$85.00

**Cross-Guide Directional Coupler,** UG-40 output flange. Main Guide is 6" Long, with 90 Deg. "E" Plane bend at one end, and is fitted with Std. UG 39/UG 40 flanges. Coupling figure: 20 db Nominal .........................$22.50

**FLEX. WAVEGUIDE SECTION,** 1 ft. long. With UG-40/UG-39 flanges. Attenuation is less than 0.1 db. at 9375 mc, and VSWR is less than 1.02. Rubber covered ......................$7.50

### JAN WAVEGUIDE FLANGES

| | | | |
|---|---|---|---|
| UG 39/U | $1.10 | UG 51/U | $1.65 |
| UG 40/U | $1.25 | UG 52/U | $3.40 |
| UG 40A/U | $1.85 | UG 52A/U | $3.40 |

**1" x ½" waveguide** in 5' lengths, UG 39 flanges to UG40 cover. Silver plated .....**per length** $5.00

**Rotating-joints** supplied either with or without deck mounting. With UG40 flanges **each,** $17.50

**Bulkhead Feed-thru Assembly** ............$15.00

**Pressure Gauge Section** 15 lb. gauge and press nipple ..................................$10.00

**Pressure Gauge,** 15 lbs. ....................$2.50

**Directional Coupler,** UG-40/U Take off 20db $17.50

**TR-ATR Duplexer** section for above ........$8.50

**Rotary joint** choke to choke with deck mounting ..................................$17.50

**90 degree elbows.** "E" plane 2½" radius ..$12.50

**Microwave Receiver,** 3 CM. Sensitivity: 10-13µ Watts. Complete with L.O. and AFC Mixer and Waveguide Input Circuits, 6 I.F. Stages give approximately 120 DV gain at a bandwidth of 1.7 MC. Video Bandwidth; 2 MC. Uses latest type AFC circuit. Complete with all tubes, including 723A/B Local Oscillator ........$175.00

**ADAPTER,** waveguide to type "N", UG 81/U, p/o TS 12, TS-13, Etc. ...................$14.50

**ADAPTER,** UG-163/U round cover to special btl. Flange for TS-45, etc. ..............$2.50 ea.

## JAN/UG CONNECTORS

| | | | | | |
|---|---|---|---|---|---|
| UG 9/U | $1.15 | UG 27A/U | $2.50 | UG 188/U | $1.20 |
| UG 10/U | 1.25 | UG 29/U | .95 | UG 254/U | 1.35 |
| UG 22/U | 1.25 | UG 58/U | .65 | UG 261/U | 1.10 |
| UG 22B/U | 1.20 | UG 85/U | 1.25 | UG 290/U | 1.15 |
| UG 24/U | 1.25 | UG 102/U | 1.85 | UG 306/U | 2.35 |
| UG 27/U | 1.20 | UG 176/U | .25 | | |

## THERMAL DELAY RELAYS

| Stock No. | Heater V | Contact* | Delay (Sec) | Price |
|---|---|---|---|---|
| 30120 | 6.3 | NC | 30 | $2.25 |
| B-1608 | 6.3 | NO | 25 | 2.40 |
| B-1612 | 6.3 | NO | 5 | 1.85 |
| 6C10 | 6.3 | NC | 10 | 1.85 |
| 12C5 | 12 | NC | 5 | 1.75 |
| 12C10 | 12 | NC | 10 | 1.85 |
| 12C45 | 12 | NC | 45 | 2.45 |
| 26N05 | 24-28 | NO | 5 | 2.25 |
| 26N010 | 24-28 | NO | 10 | 2.25 |
| 26N015 | 24-28 | NO | 15 | 2.40 |
| 26N020 | 24-28 | NO | 20 | 2.40 |
| 26N030 | 24-28 | NO | 30 | 2.40 |
| 26N060 | 24-28 | NO | 60 | 2.40 |

* NO—Normally open, NC—Normally closed. All contact ratings are 3A at 115 VDC or 250 VAC, and are SPST. Units are enclosed in glass tube envelope with octal base.

## MAGNETRONS

| Type | Peak Range (MC) | Peak Power Out (KW) | Duty Ratio | Price |
|---|---|---|---|---|
| 2J21A | 3345-9405 | 50 | | $ 8.75 |
| 2J22 | 3267-3333 | 265 | | 7.50 |
| 2J26 | 2992-3019 | 275 | .002 | 7.49 |
| 2J27 | 2965-2992 | 275 | .002 | 13.50 |
| 2J29 | 2914-2939 | 275 | .002 | 44.95 |
| 2J31 | 2820-2860 | 285 | .002 | 21.50 |
| 2J32 | 2780-2820 | 285 | .002 | 21.50 |
| 2J38* | 3249-3263 | 5 | | 8.50 |
| 2J39* | 3267-3333 | 8.7 | | 8.50 |
| 2J48 | 9310-9320 | 50 | .001 | 24.50 |
| 2J49 | 9000-9160 | 50 | .001 | 54.50 |
| 2J56* | 9215-9275 | 50 | .001 | 132.50 |
| 2J62† | 2914-3010 | 35 | .002 | 32.50 |
| 3J31 | 24-27KMC | 50 | .001 | 85.00 |
| 4J34 | 2740-2780 | 900 | | 87.50 |
| 4J38 | 3550-3600 | 750 | .001 | 125.00 |
| 4J42† | 670-730 | 30 | .003 | 169.50 |
| 5J23 | 1044-1056 | 475 | .001 | 49.50 |
| 700B | 690-700 | 40 | .002 | 22.50 |
| 700D | 710-720 | 40 | .002 | 39.75 |
| 706EY | 3038-3069 | 200 | .001 | 32.50 |
| 706CY | 2976-3007 | 200 | .001 | 32.50 |
| QK259† | 2700-2900 | 800 | .001 | 249.50 |
| QK60†* | 2840-3005 | .100 | CW | 65.00 |
| QK61†* | 2975-3170 | .100 | CW | 65.00 |
| QK62†* | 3135-3350 | .100 | CW | 65.00 |

*—Packaged with magnet.
†—Tunable over indicated range.

## TEST EQUIPMENT

| | | |
|---|---|---|
| IE 19 | TS 34 A | TS 100 |
| IE 36 | TS 35 A | TS 110 |
| I-104 | TS 56 A | TS 159 TPX |
| TS 10 A | TS 47 APR | TS 268/U |
| TS 16 | TS 100 | TSX 4 SE |

## POWER TRANSFORMERS

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CT-127 900V/25MA PK. 5V/2A, 2V/7.5A ...... 2.79
CT-006 350-0-350V/120MA, 5VCT/3A, 2.5VCT/12.5A, 2.5VCT/3.5A ........ 6.10
CT-965 78V/0.6A, 6.3V/2A .................. 1.95
CT-004 350-0-350V/90MA, 5VCT/3A, 2.5VCT/12.5A .................. 4.60
CT-002 350-0-350V/50MA, 5VCT/2A, 2.5VCT/7.5A .................. 3.65
CT-479 7000V/.018A (2 X Ind. V. Test) 2.5V 5A/17,800 V. Test .................. 29.50
CT-013 450-0-450V @ 200MA, 10V/1.5A, 2.5V 3.5A 5V/3A .................. 6.95
CT-403 350VCT .026A 5V/3A .................. 2.75
CT-931 585VCT .086A 5V/3A, 6.3V/6A ....... 4.25
CT-442 525VCT 75MA 5V/2A, 1CT/2A, 50V/200 MA .................. 3.85

### PLATE—115V/60 ~ INPUT

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PT 168 2100-0-2100 VAC (1750VDC) or 1800-0-1800 VAC (1500VDC) at 300 MADC 33.00
PT 371 210-0-210V at 2.12 Amp. .............. 9.45
PT 133 3140/1570V. 2.36KVA ..............105.00
PT 801 22,000V/234 MA., 5.35 KVA ...........135.00
PT 521 7500V/.06A, Half-Wave .............. 85.00
PT 913 2500V/12 MA H'SLD .............. 4.95
PT 12A 280VCT/1.2A .............. 3.95
PT-38-2 37.5/40V AT 750 MA .............. 2.15

## PULSE NETWORKS

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**G.E. #3E** (3-84-810) 8-2.24-405) 50P4T ; 3KV "E" CKT Dual Unit: Unit 1, 3 sections, 0.84 Microsec. 810 PPS, 50 ohms imp.; Unit 2, 8 Sections, 2.24 microsec. 405 PPS 50 ohms imp. ..............$6.50

**7-5E3-1-200-67P.** 7.5 KV "E" Circuit, 1 microsec. 200 PPS, 67 ohms impedance 3 sections ...........$7.50

**7-5E4-16-60,** 67P. 7.5 KV "E" Circuit, 4 sections 16 microsec. 60 PPS, 67 ohms impedance .......$15.00

**7-5E3-3-200-67P,** 7.5 KV, "E" Circuit, 3 microsec. 200 PPS. ohms imp. 3 sections ..................$12.50

**#755: 10KV.** 2.2usec., 375 PPS. 50 ohms imp. ...$27.50

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**G.E.** 6E3-.5-2000 50 P2T: 6 KV., "E" Circuit 0.5 usec /2000 PPS/50 ohms/2 sections .................$7.50

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**MIT. MOD. 3 HARD TUBE PULSER:** Output Pulse Power 144 KW (12 KV at 12 Amp). Duty Ratio: .001 max. Pulse duration: 5, 1.0, 2.0 microsec. Input voltage: 115 v. 400 to 2400 cps. Uses: 1-71B, 4-89-B, 3-'72's, 1-'73. New ...............Less Cover—$135

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Primary: 9.33 KV, 50 ohms Imp.
Secondary: 28 KV, 450 ohms.
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Bifilar: 1.5 amps (as shown) ...$62.50

**GE #K-2748-A.** 0.5 usec @ 2000 Pps. Pk. Pwr. out is 32 KW impedance 40:100 ohm output. Pri. volts 2.3 KV Pk. Sec. volts 11.5 KV Pk. Bifilar rated at 1.3 Amp. Fitted with magnetron well ........$39.50

**K-2745** Primary: 3.1/2.8 KV, 50 ohms Z. Secondary: 14/12.6 KV 1025 ohms Z. Pulse Length: 0.25/1.0 usec @ 600/600 PPS. Pk. Power 200/150 KW. Bifilar: 1.3 Amp. Has "built-in" magnetron well ........................................$42.50

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**K35J45**—Pulse Inversion: PRI: 5 KV PK. Pulse Negative. Sec: Pos. Pulse, 4 KV; 1 usec. and .001 DUTY RATIO ..........................$6.50

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**TR1049** Ratio 2:1 Pri. 220 MH. 50 Ohms, sec. 0.75 H. DCR 100 Ohms ...........................$6.75

**K-904695-501:** Ratio 1:1. Pri. Imp. 40 Ohm, Sec. Imp. 40 Ohms. Passes pulse 0.6 usec with 0.05 usec rise ........................................$8.95

**Ray UX 7896**—Pulse Output Pri, 5v sec. 41v ....$7.50

## DELAY NETWORKS

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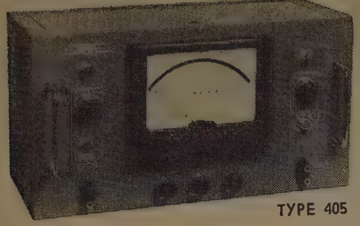

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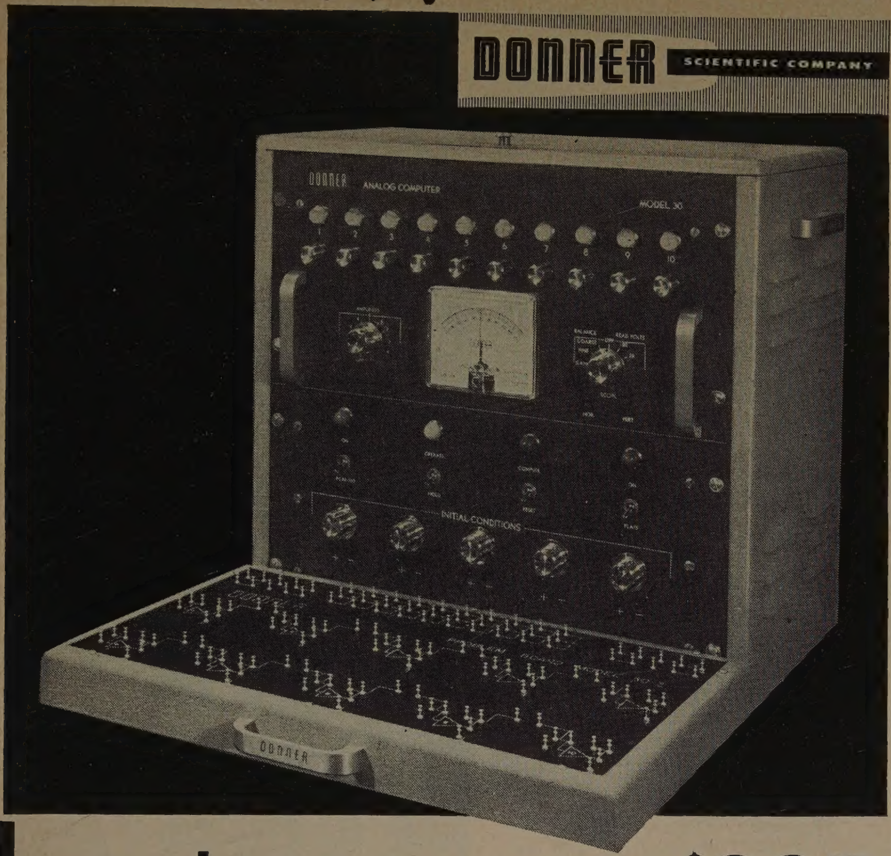

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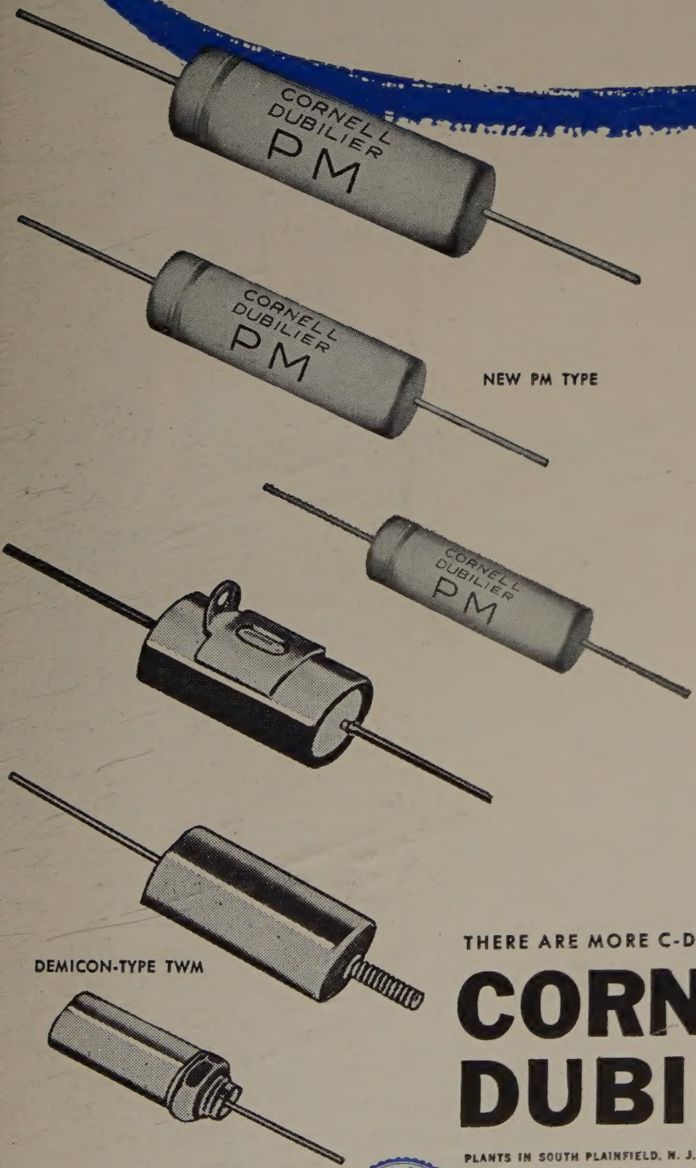

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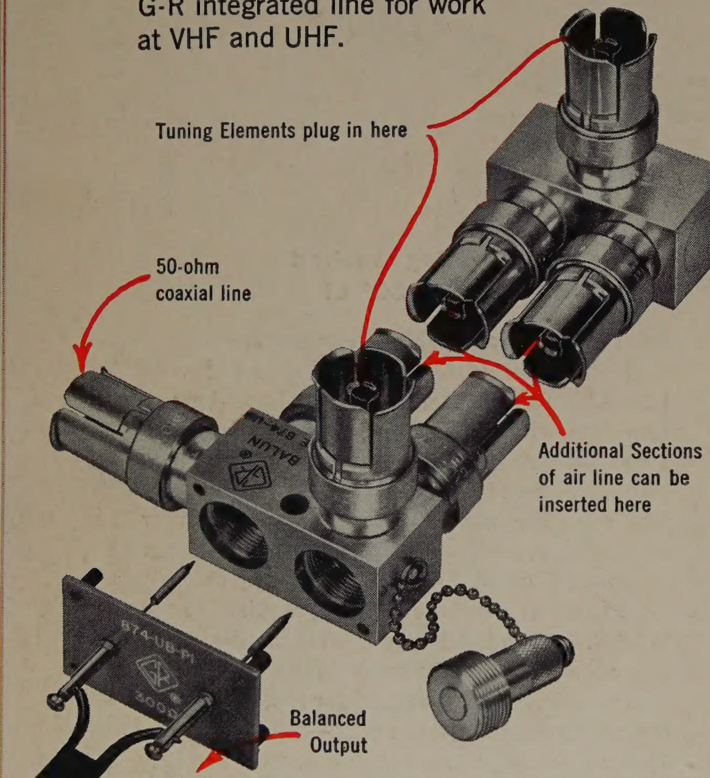
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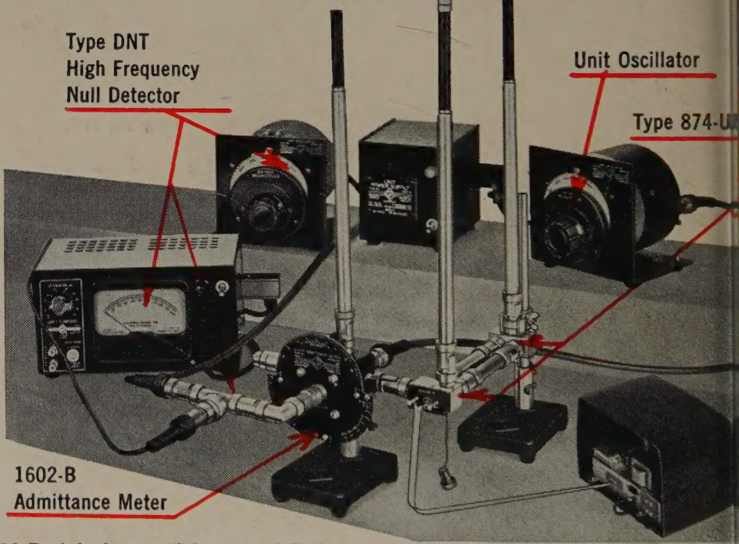

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